CLIMATE RISK COUNTRY PROFILE

MEXICO

WORLD BANK GROUP

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ACKNOWLEDGEMENTS

This profile is part of a series of Climate Risk Country Profiles developed by Climate Change Group of the World Bank Group (WBG). The country profiles aim to present a high-level assessment of the climate risks faced by countries, including rapid-onset events and slow-onset changes in climate conditions, many of which are already underway, as well as summarize relevant information on policy and planning efforts at the country level.

The country profile series are designed to be a reference source for development practitioners to better integrate detailed climate data, physical climate risks and need for resilience in development planning and policy making.

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Unless otherwise noted, data is sourced from the WBG's Climate Change Knowledge Portal (CCKP), the WBG's designated platform for climate data. Climate, climate change and climate-related data and information on CCKP represents the latest available data and analysis based on the latest Intergovernmental Panel on Climate Change (IPCC) reports and datasets. The team is grateful for all comments received from climate and development specialists, as well as climate research scientists and institutions for their advice and guidance on the use of climate related datasets.

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FOREWORD

Climate change is a major risk to good development outcomes and presents an existential threat to the World Bank Group's (WBG) twin goals of ending extreme poverty and promoting shared prosperity in a sustainable way. The WBG is thus committed to supporting client countries to invest in a low-carbon and climate-resilient future.

Our approach is outlined in the *WBG Climate Change Action Plan (CCAP) 2021–2025*, which focuses on helping countries integrate climate into their development agendas, with the goal to combine mitigation and adaptation with economic growth and poverty reduction. Guided by the *CCAP*, the WBG prioritizes climate action across five key systems: energy; agriculture, food, water, and land; cities; transport; and manufacturing. Only through transforming these systems can we begin to address climate change, achieve a resilient and low-carbon future, and support natural capital and biodiversity, while achieving development goals.

A key element of this strategy relies on the capacity to systematically incorporate and manage climate risks in development operations. We are thus investing in processes and tools that allow us to inform lending with climate data.

The Climate Change Knowledge Portal (CCKP) is an online 'one-stop-shop' for foundational climate data at the global, regional, and country levels. CCKP provides inputs to the WBG's Climate and Disaster Risk Screening Tool, which contributes to assessing short- and long-term climate and disaster risks in operations as well as national or sectoral planning processes.

Supplementing this effort, the *Climate Risk Country Profile* you are about to read is a signature product of CCKP which supports a better understanding of the impacts of physical climate risks. Guided by the Climate Risk Country Profile, WBG, key external partners, and development practitioners may conduct initial assessments of climate risks and opportunities that will eventually inform upstream country diagnostics, policy dialogue, and strategic planning for developing countries.

It is my hope that these efforts will spur the prioritization of long-term risk management and deepen the WBG's commitment to integrate adaptation planning into strategic country engagements and lending operations.

Jennifer J. Sara
Global Director
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KEY MESSAGES

- **Observed Climate:** Mexico's climate features a wide range of temperature distributions, one rainy and dry season annually at different times depending on the region, and several strong influencing factors – the Intertropical Convergence Zone (ITCZ) and associated monsoon, mountainous topography, and the El Niño Southern Oscillation (ENSO).
- **Observed Temperature:** Between 1971 and 2020, Mexico's mean temperature increased by 0.31°C per decade.
  - **The Northern Plateau** observed the greatest changes over this period during the summer months.
- **Projected Temperature:** Under the SSP3-7.0 ensemble, Mexico's annual mean temperature nationwide is projected to increase 0.82°C (0.47°C, 1.21°C) from the historical reference period of 1995–2014 to 22.02°C (21.46°C, 22.62°C) for the period 2020–2039, and 1.63°C (1.20°C, 2.20°C) to 22.83°C (22.18°C, 23.64°C) for the period 2040–2059.
  - At least one state from **each region** is expected to endure conditions characteristic of different climatic zones by midcentury under SSP3-7.0.
- **Extreme Heat Risk:** By midcentury, Mexico is likely to experience higher minimum and maximum temperatures, and hotter apparent conditions due to high atmospheric moisture content. The following key metrics for temperature illustrate these risks under the SSP3-7.0 scenario for the period of 2040–2059, compared to the historical reference period of 1995–2014.
  - Number of High Heat Index Days, Days Surpassing Heat Index of 35°C: Mexico's high atmospheric moisture content over certain coastal regions makes the projected number of days surpassing the Heat Index >35°C increase to above 20 days per month during the summer season by midcentury. This not only exacerbates human health concerns, but also presents risks to the water resources and agriculture sectors.
    - **The Eastern coast** observed the greatest increases during the summer months by midcentury.
  - Summer Days, T-max >25°C: The number of days nationwide with a maximum temperature >25°C increase 34.53 (24.38, 48.32) to 277.90 (258.61, 294.73) days annually by 2040–2059 from the reference period. An increase in the number of summer days with high maximum temperature thresholds coupled with tropical nights with high minimum temperature thresholds present elevated risks of prolonged heat exposure.
    - **The Northern and Central Plateaus** are projected to experience the greatest year-round increases in summer days by midcentury, but **areas of higher elevations in each region** are expected to observe increases.
  - Number of Tropical Nights, T-min >20°C: The number of annual nights with a minimum temperature >20°C is projected to increase 29.01 (19.58, 40.83) to 128.26 (114.04, 143.17) nights nationally by 2040–2059 from the reference period. The combination of increased high heat days and tropical nights disproportionately concern: the elderly, pregnant women, children and newborns, people with chronic illnesses and disabilities, outdoor workers, low-wage earners, and people living in areas with poorly equipped and ill-prepared health services.
    - **Southern Mexico** is projected to experience the greatest increases by midcentury during different seasonal peaks.
  - Warm Spell Duration Index: This annualized index indicates the number days with consecutive daily maximum temperatures greater than the 90th percentile of daily maximum temperature calculated over a five-day window annually. Warm spell anomalies, measured in number of days annually, are projected to increase 74.81 (34.73,125.09) days by midcentury, more than tripling from its 2020–2039 anomaly. This shift reflects a longer-term change in daily maximum temperatures.
    - The **Southern Pacific and Caribbean coasts** are projected to experience the greatest increases in warm spells by midcentury.

- **<u>Observed Precipitation:</u>** Over the 50-year period of 1971–2020, Mexico experienced significant decreases in precipitation per decade across some states but significant increases in precipitation across others. Over this period:
  - **States in the far north and Yucatán Peninsula** were significantly drier, especially during summer months.
  - **States along the Cordillera Neo-Volcánica and Sierra Madre del Sur** were significantly wetter during summer and fall months.
  - **The central Gulf of California (Baja California Sur)** was also significantly wetter during fall months.
- **<u>Projected Precipitation:</u>** Projected precipitation patterns under SSP3-7.0 reflect regional shifts in seasonal onset and intensity by midcentury, but trend toward a nationwide annual decrease.
  - The **Southern Pacific coast and Nayarit** are expected to experience the greatest annual percentage decrease in precipitation by 2040–2059 under SSP3-7.0, while the **Eastern coastal states** are expected to experience the greatest decline in volume over the same time period.
  - **Northwest Mexico (except for Nayarit and Sinaloa)** is projected to experience slight percentage increases in precipitation by midcentury.
- **<u>Precipitation Risk:</u>** By midcentury, Mexico is likely to experience greater precipitation intensities, though the timing and extent of extreme anomalies vary by state. The following key metrics for precipitation illustrate these shifts for the period of 2040–2059 under SSP3-7.0, compared to the historical reference period of 1995–2014.
  - <u>Average Largest 5-Day Precipitation:</u> Increases in the average largest precipitation amount over a 5-day period pose risks for flood management and do not always coincide with months experiencing the largest anomalies in total projected precipitation volumes.
    - **The Yucatán Peninsula and Tamaulipas** are expected to experience the biggest changes in average largest 5-day precipitation by midcentury, though parts of the **Southern Pacific coast and Central Mexico** feature monthly increases that other monthly decreases offset.
- **<u>Extreme Precipitation Occurrence:</u>** By midcentury, Mexico is likely to more frequently experience extreme precipitation event occurrence. These conditions pose risks for food security, flood-related safety, disease ranges, biodiversity, and living conditions.
  - **The Central and Northern Plateaus and parts of the Gulf coast** are projected to be nearly twice as likely or more than twice as likely to experience extreme precipitation events with 100-year historical return periods by midcentury under SSP3-7.0.
- **<u>Climate-Related Hazards:</u>**
  - Sea level rise and coastal inundation will increasingly threaten the **Gulf of California, parts of the Southern Pacific, Gulf of Mexico, and Caribbean coast**. Observed sea surface temperatures off the **Pacific coast of Baja California** have increased the most over the last 30-year climatology, but varying rates of change between and within its Pacific and Atlantic coasts also correlate with interannual and decadal climate patterns.
  - Incidents of both flooding and drought in Mexico will likely occur with greater intensity and frequency in the future but are strongly influenced by ENSO. More intense droughts are likely to occur in the **Northern Plateau region** and more extreme flooding is especially likely along the **Southern (Pacific) coast.**
  - Climate variability exacerbates high seismic risks that threaten much of the country's most densely populated centers. The **Southern (Pacific) coast and Cordillera Neo-Volcánica** have the greatest seismic risks threatened by future climate variability.

For National Policies, see key documents linked at the end of this profile.

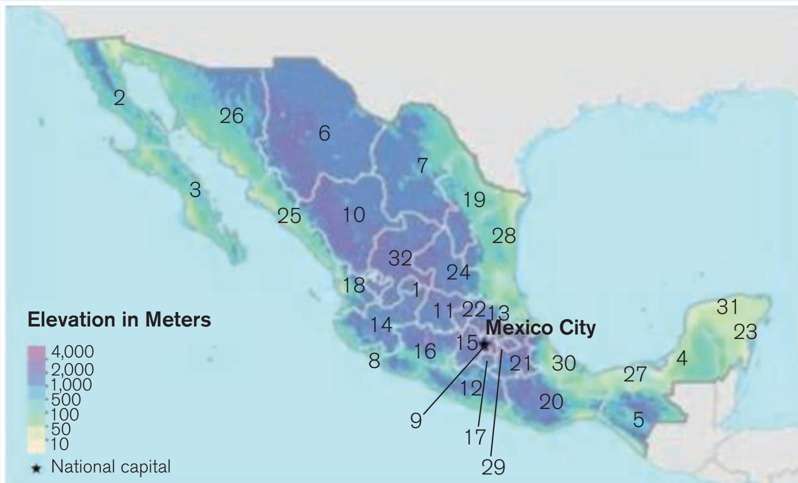
COUNTRY OVERVIEW

Mexico is the northernmost country in Latin America between 14°–33°N latitude, home to a wide range of diverse regions spanning across its 31 states and federal capital district (**see Figures 1a and 1b)**. The country is considered the 13th largest nation in the world, covering 1.96 million km^2 of land, and features three main topo-geographic zones: coastal lowlands along the Pacific Ocean and Gulf of Mexico, a relatively arid central plateau, and in between, tall mountain chains defining its western, eastern, and southern extents.[1] On Mexico's western Pacific coast is the 1,300 kilometer (km) long Baja California Peninsula, which has elevations of more than 2,700 meters (m) along its spine. The Pacific coastal lowlands border the eastern Gulf of California, also known as the Sea of Cortez, from the Colorado River Delta in the north to the state of Nayarit in the south. The comparatively wider coastal plain along the eastern Gulf of Mexico extends about 1,450 km southeast from the Rio Grande River (or Río Bravo del Norte) on the U.S. border to the Isthmus of Tehuantepec. In the far east, the low-lying Yucatán Peninsula separates the Gulf of Mexico and the Caribbean Sea. Mexico's main mountain chains include: the Sierra Madre Occidental in the west (2,400–2,700 m above sea level on average); the Sierra Madre Oriental in the east (with peaks above 3,650 m above sea level); the Cordillera Neo-Volcánica, which links the two from east to west across Mexico's center and boasts the country's highest point Pico de Orizaba (5,610 m above sea level); and the Southern Highlands to the south (2,100–2,400 m above sea level), comprising the Sierra Madre del Sur and the Chiapas Highlands, which extend into Guatemala and Belize.[2] The Mexican Plateau is an elevated series of intermontane basins bounded by the western Sierras, eastern Sierras, and southern Neo-Volcánica mountain ranges. In the north, the sparsely populated Mesa del Norte begins in the Chihuahua Desert at about 1,200 m above sea level. In the south, the moister central Mesa de Anáhuac is where most of Mexico's population is concentrated, rising 2,100–2,700 m above sea level.

[1] Meyer, M. C., Bernstein, M. D., and Willey, G. R. (2023). Mexico. Encyclopedia Britannica. URL: https://www.britannica.com/place/Mexico

[2] The Sierra Madre Occidental runs from Sonora in the north through Chihuahua, Durango, Sinaloa, Zacatecas, Aguascalientes, Nayarit, Jalisco, and terminates in Guanajuato to the south, where it joins the Cordillera Neo-Volcánica. The Sierra Madre Oriental runs from Coahuila's U.S. border in the north through Nuevo León, Tamaulipas, San Luis Potosí, Querétaro, Hidalgo, and terminates in Puebla to the south, where it joins the Cordillera Neo-Volcánica. This Cordillera runs from Jalisco in the west through Michoacán, Guanajuato, Querétaro, Hidalgo, México, Ciudad de México, Morelos, Puebla, Tlaxcala, and terminates in Veracruz to the east. The Southern Highlands include the Sierra Made del Sur – which runs from Jalisco in the west through Michoacán, Guerrero, and Oaxaca – and the Chiapas Highlands, which run from the Isthmus of Tehuantepec eastward to the Guatemala border.

FIGURE 1A. Topography of Mexico[3]



Note coastal lowlands in light green, mountain chains in purple, and plateau in expansive areas of dark blue.

FIGURE 1B. Climate Regions of Mexico[4]

Note parallels with topographic diversity in **Figure 1a**.

[3] Mexico's states are numbered in Figure 1 as follows: 1 – Aguascalientes, 2 – Baja California, 3 – Baja California Sur, 4 – Campeche, 5 – Chiapas, 6 – Chihuahua, 7 – Coahuila, 8 – Colima, 9 – Ciudad de México (formerly Distrito Federal), 10 – Durango, 11 – Guanajuato, 12 – Guerrero, 13 – Hidalgo, 14 – Jalisco, 15 – México, 16 – Michoacán, 17 – Morelos, 18 – Nayarit, 19 – Nuevo León, 20 – Oaxaca, 21 – Puebla, 22 – Querétaro, 23 – Quintana Roo, 24 – San Luis Potosí, 25 – Sinaloa, 26 – Sonora, 27 – Tabasco, 28 – Tamaulipas, 29 – Tlaxcala, 30 – Veracruz, 31 – Yucatán, and 32 – Zacatecas.

[4] Sayre, R., Karagulle, D., Frye, C., Boucher, T., Wolff, N. H., Breyer, S., et al. (2020). An assessment of the representation of ecosystems in global protected areas using new maps of World Climate Regions and World Ecosystems. Global Ecology and Conservation, 21, e00860. DOI: https://doi.org/10.1016/j.gecco.2019.e00860

According to the World Bank's Data Bank,[5] Mexico is classified as an upper middle-income country and the second-largest economy in Latin America after Brazil. Mexico has a total population of 127.5 million people, 10th in the world, and a 2022 annual population growth rate at 0.6%. Approximately 81% of the 2022 population lives in urban areas, with roughly 18% residing in slums as of 2020. Overall, Mexico ranks relatively high on the Human Development Index (86 out of 191) for 2021, considering factors such as life expectancy, education, and income per capita.[6] In 2022, the country had a Gross Domestic Product (GDP) of $1.41 trillion (in $U.S.), an annual growth rate of 3.1%, and a GDP per capita of $11,091.31 ($U.S.). Following reforms to boost deregulation, privatization, foreign investment, and free trade during the 1980s and 1990s, Mexico expanded its export-oriented industrial and manufacturing base.[7] Recent investments have also targeted its key petroleum industry along the Gulf coast. A diversified service sector – including finance, trade, and tourism, especially with the U.S. – accounts for approximately two-thirds of its GDP. Though activities supporting coffee, sugarcane, maize, livestock ranching, and other agricultural products account for a lower proportion of overall employment and GDP (**Table 1**), they employ nearly half of Mexico's rural population.[8] However, despite its upper middle-income status, Mexico has high rates of socioeconomic inequality and faces challenges in reducing poverty among rural indigenous communities. Whereas only 3.1% of the 2020 population was living below a threshold of $2.15 a day purchasing power parity (PPP as of 2017), 43.9% of its population lives below the nationally determined poverty line, a high level globally.

TABLE 1. Key Development Indicators[9]

Key Demographic Indicators	Most Recent Value	Global Rank
Population Density (people per sq km, 2020)	64.82	137 (out of 215)
Life Expectancy (for total population in years, 2021)	70.21	135 (out of 209)
Fertility Rate (total births per woman, 2021)	1.82	120 (out of 210)
Dependency Ratio (dependents per 100 working-age people, 2022)	48.88	155 (out of 217)
Key Economic and Social Development Indicators	**Most Recent Value**	**Global Rank**
GDP per Capita (in current $US, 2022)	$11,091.31	73 (out of 186)
% Population Below National Poverty Line (2020)[10]	43.90%	23 (out of 100)
Unemployment Rate (% of total labor force, 2022)	3.39%	151 (out of 183)
% Employed in Agriculture (2021)	12.33%	107 (out of 185)
% Employed in Industry (2021)	25.64%	40 (out of 185)
% Employed in Services (2021)	62.02%	81 (out of 185)
% Population with Access to Electricity (2021)	100%	1 (tied, out of 215)
% Population Using at Least Basic Sanitation Services (2020)	92.42%	92 (out of 188)

Data for each indicator's most recently measured year is ranked compared to all countries and entities globally in the far-right column, as tracked by the World Bank's Data Bank. Global ranking for the population experiencing multidimensional poverty only includes countries classified as developing by UNDP.

[5] World Bank (2023). DataBank – World Development Indicators. URL: https://databank.worldbank.org/source/world-development-indicators

[6] UNDP (2022). Human Development Report 2021/2022. URL: https://hdr.undp.org/system/files/documents/global-report-document/hdr2021-22pdf_1.pdf

[7] Meyer, M. C., Bernstein, M. D., and Willey, G. R. (2023). Mexico. Encyclopedia Britannica. URL: https://www.britannica.com/place/Mexico

[8] World Bank, CIAT, and CATIE (2015). Climate-Smart Agriculture in Mexico. URL: https://cgspace.cgiar.org/bitstream/handle/10568/49671/CSA-in-Mexico.pdf?sequence=21&isAllowed=y

[9] World Bank (2023). DataBank – World Development Indicators. URL: https://databank.worldbank.org/source/world-development-indicators

[10] UNDP (2022). Global Multidimensional Poverty Index 2022. URL: https://hdr.undp.org/system/files/documents/hdp-document/2022mpireportenpdf.pdf

In 2022, Mexico submitted an updated Nationally Determined Contribution (NDC) and a Third Biennial Update Report (BUR3) to the UNFCCC. Mexico's revised NDC unconditionally commits to a greater percent reduction in greenhouse gas emissions from 22% to 35% by 2030 using a recalculated business-as-usual baseline. It also reiterates the country's adaptation priorities according to five strategic axes: preventing adverse impacts among vulnerable populations, building resilient food production systems, sustainably managing biodiversity and ecosystem services, supporting comprehensive water resource management, and protecting critical infrastructure and cultural heritage.[11] To align with its revised NDC, the Mexican government amended its General Law on Climate Change (LGCC), which established an institutional and legal framework for climate mitigation and adaptation. According to Mexico's Third Biennial Report, 68% of the country's population and 71% of its GDP are exposed to climate impacts,[12] with municipalities at greatest risk identified by the *National Atlas of Vulnerability to Climate Change* (ANVCC).[13]

OBSERVED AND CURRENT CLIMATE

Data Overview

The data presented are from the World Bank Group's Climate Change Knowledge Portal (CCKP).[14] Historical, observed data is derived from the Climatic Research Unit, University of East Anglia (CRU), CRU TS version 4.07 gridded dataset (data available 1901–2022) and ERA5 reanalysis collection from ECMWF (1950–2020).

Climate Overview

Mexico's climate features a wide range of temperature distributions, one rainy and dry season annually at different times depending on the region, and several strong influencing factors – the Intertropical Convergence Zone (ITCZ) and associated monsoon, mountainous topography, and the El Niño Southern Oscillation (ENSO). Over the current climatology (1991–2020, **see Figure 2a**), Mexico experienced a mean annual temperature of 21.31°C. During the 1991–2020 period, average seasonal temperatures observed over the typically warmer months (May–September) ranged from an average minimum temperature of 17.59°C in September to an average maximum temperature of 33.17°C in June. Over the cooler months (November–March), temperatures ranged from a minimum average of 7.98°C in January to a maximum average of 27.95°C in March. However, given the heterogeneity of climate across the country, it is important to consider which of three main climate classifications prevail at a subnational level.[15] A hot tropical zone (*tierra caliente*) covers all areas below

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[11] Government of Mexico (2022). Nationally Determined Contributions – 2022 Update. URL: https://unfccc.int/sites/default/files/NDC/2022-11/Mexico_NDC_UNFCCC_update2022_FINAL.pdf

[12] Ministry of Environment and Natural Resources (2022). Tercer Informe Bienal de Actualización ante la Convención Marco de las Naciones Unidas sobre el Cambio Climático. URL: https://unfccc.int/sites/default/files/resource/Mexico_3er_BUR.pdf

[13] INECC (2021). Municipios Vulnerables al Cambio Climático con base en los resultados del Atlas Nacional de Vulnerabilidad al Cambio Climático. URL: https://atlasvulnerabilidad.inecc.gob.mx/conten_intro/Mpos_Vulnerables_priorizacion_ANVCC.pdf

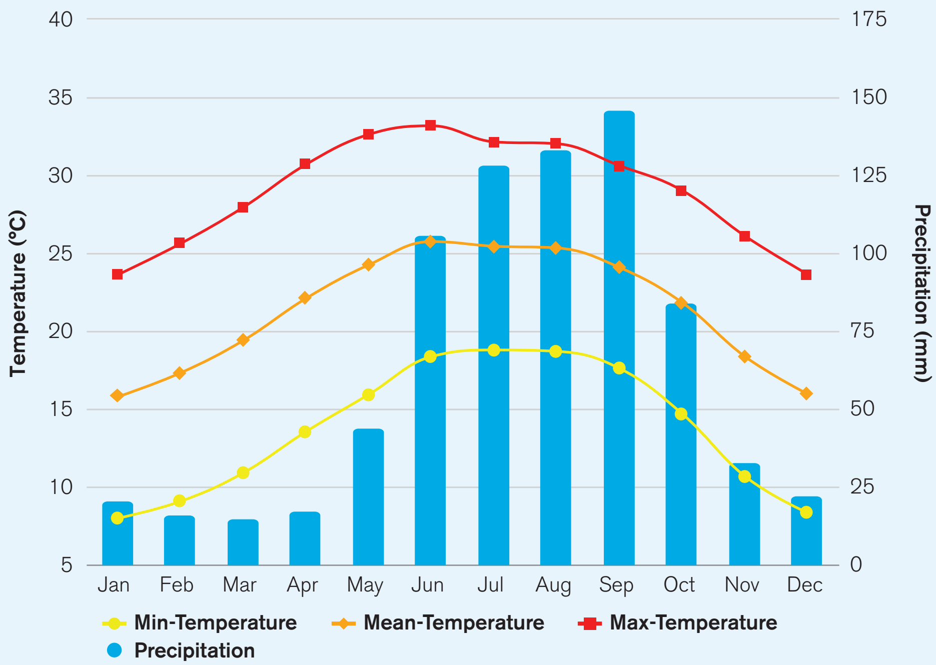
[14] World Bank Climate Change Knowledge Portal (2023). Mexico Climatology. URL: https://climateknowledgeportal.worldbank.org/country/mexico/climate-data-historical

[15] Meyer, M. C., Bernstein, M. D., and Willey, G. R. (2023). Mexico. Encyclopedia Britannica. URL: https://www.britannica.com/place/Mexico

900 m and exhibits mean annual temperatures around 25°C. Mexico's climate is tropical along most of the low-lying Pacific coast, Yucatán Peninsula, and Isthmus of Tehuantepec (**see Figure 2b**). A zone of milder temperatures (*tierra templada*) is located between 900 m–1,800 m, with mean annual temperatures of approximately 18–19°C. Much of the Southern Highlands and parts of the Northern Plateau are subtropical due to their altitude. However, the southern Baja California Peninsula and eastern Gulf Coast lowlands are subtropical due to their higher latitude. A temperate zone (*tierra fría*) occupies even higher altitudes up to 3,350 m, with mean annual temperatures around 15°C. The Sierras, Central Mexican Plateau, and northern Baja California Peninsula (**see Figures 2c–d**) experience temperate conditions. **Table 2** describes temperature and precipitation characteristics in greater detail for states in each of Mexico's five identified climatic-topographic regions.

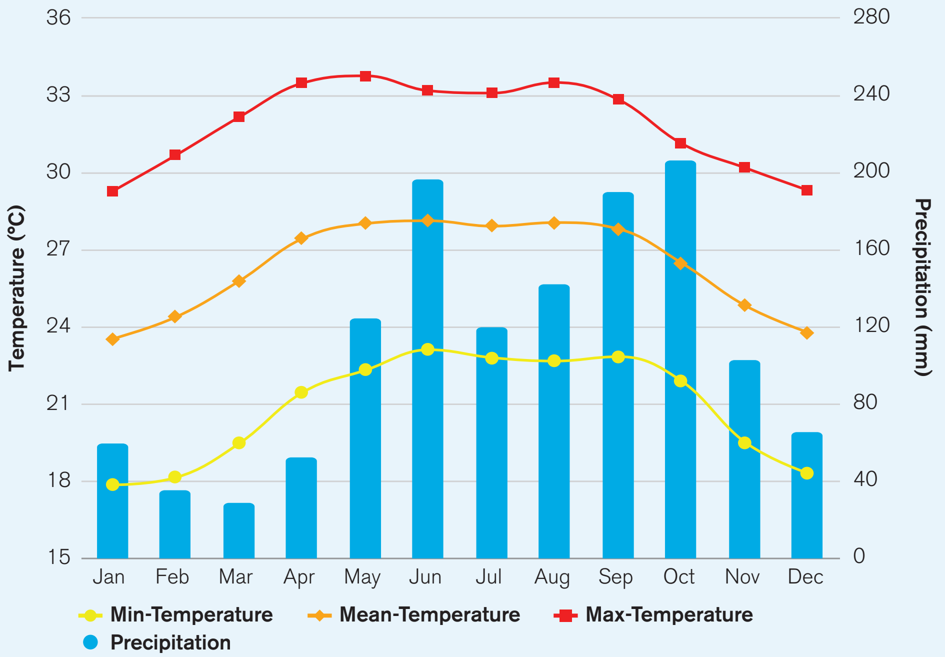
Mean annual precipitation over the current climatology (1991–2020) at the national level was 764.19 mm, more than three-quarters of which fell during the May to October rainy season. Yet there are significant regional patterns and seasonal distributions (**see Figures 2b–d**). The eastern (Gulf and Caribbean) coasts received the highest annual rainfall amounts over this 30-year period (greater than 1,000 mm). The Yucatán Peninsula and Isthmus of Tehuantepec experienced heavy precipitation almost the entire year. Meanwhile, most of the country north of the Tropic of Cancer, including the Mexican Plateau, Baja California Peninsula, and Sonoran and Chihuahuan Deserts, received low amounts of precipitation (less than 700 mm per year). The Sierras along the western, eastern, and southern coasts received comparably higher seasonal volumes of rainfall (mostly between 600–1,400 mm annually). As illustrated in **Table 2**, the onset of the rainy season in southern Mexico begins in late May, when the ITCZ migrates northward. This is also when easterly summer trade winds transfer moisture from the Caribbean Sea and Gulf of Mexico, which intensify from June to July and lead to the westward displacement of the ITCZ over Mexico's Eastern

FIGURE 2A. Observed Monthly Climatology of Mexico's Temperature and Precipitation, 1991–2020



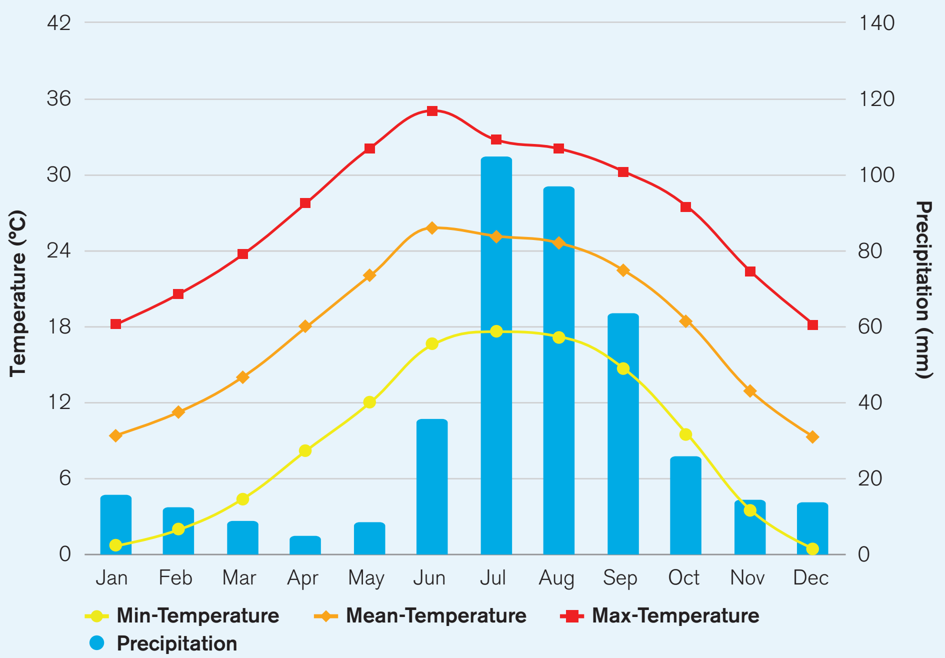
This nationwide distribution reflects diverse regional temperature and precipitation regimes.

FIGURE 2B. Observed Monthly Climatology of Quintana Roo's Temperature and Precipitation, 1991–2020



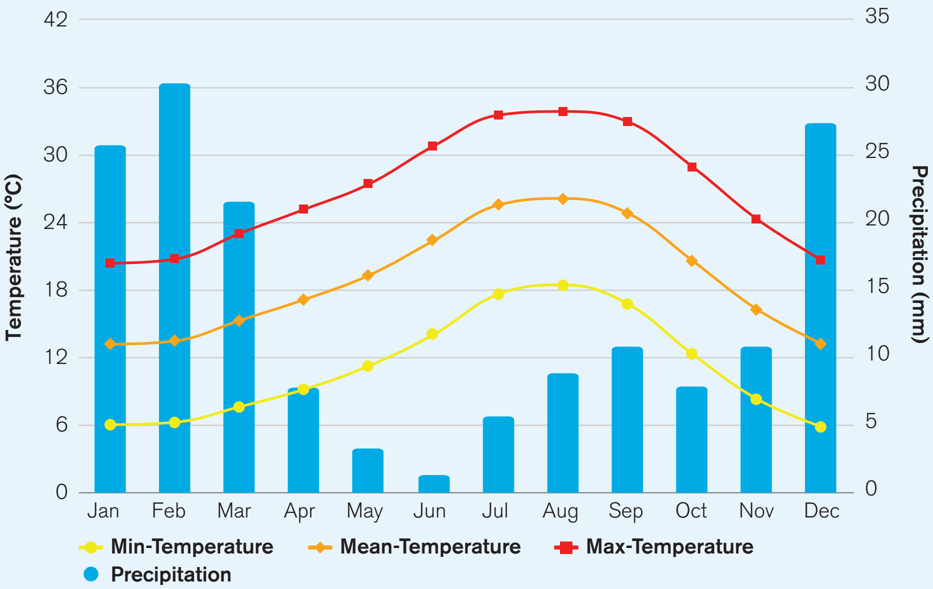
This precipitation regime along the Caribbean coast contains a noticeable midsummer precipitation minimum. Note the timing and intensity of the warmest months (May–September) and the driest months (December–April). The scale on the y-axis reflects warmer than average temperatures and higher than average total precipitation values.

FIGURE 2C. Observed Monthly Climatology of Chihuahua's Temperature and Precipitation, 1991–2020



This climate regime in the northern Mexican Plateau has more pronounced temperature and precipitation extremes. Note peak high temperatures and short wet season in the summer, and low temperatures and long dry season in the winter. The scale on the y-axis reflects a greater than average temperature range and lower than average total precipitation values.

FIGURE 2D. Observed Monthly Climatology of Baja California's Temperature and Precipitation, 1991–2020



This climate regime on Mexico's northwest coast is characterized by a summer dry season, winter rainy season, and lower than average annual precipitation values. The scale on the y-axis reflects a greater than average temperature range and lower than average total precipitation values.

Pacific coast.[16] Stronger easterlies produce a notable midsummer precipitation minimum during July and August in Mexico's southeast, most distinguishable in Quintana Roo and Chiapas.[17] During July, precipitation associated with the North American Monsoon also intensifies in Mexico's Northwest, causing prevailing winds to shift southerly until September from the state of Sinaloa northward along the entire length of the warm Gulf of California.[18] As the ITCZ retreats southward, the dry season begins nationally around November and lasts until April, during which westerly winds prevail in the north. The remainder of this section highlights temperature and precipitation variations within each region detailed in **Table 2**.

Between 1991 and 2020, Mexico's eastern Gulf and Caribbean coasts experienced the warmest mean temperatures and highest amounts of annual rainfall. The state of Tabasco on the Isthmus of Tehuantepec observed the region's warmest monthly mean in May (29.40°C) and wettest monthly precipitation (406.03 mm in October). It also observed the highest annual precipitation nationally (2,300.54 mm), partly due to a longer wet season, and the warmest annual mean temperature nationally (27.12°C), due to its low-lying location closer to the Equator. Veracruz, with higher latitudes and topography, observed the region's coolest monthly mean in January (20.37°C) whereas the rest of the region's states observed an average range between minimum and maximum temperatures of 17°C–30°C during their coolest month. All of Mexico's eastern states observed average maximum temperatures of 33°C or more during their warmest

16 Magaña, V., and Diaz, S. (2022). Inter ocean basin moisture fluxes and the onset of the summer rainy season over southern Mexico. Frontiers in Climate, 4, 1037350. DOI: https://doi.org/10.3389/fclim.2022.1037350

17 Magaña, V., Amador, J. A., and Medina, S. (1999). The midsummer drought over Mexico and Central America. Journal of Climate, 12(6), 1577–1588. DOI: https://doi.org/10.1175/1520-0442(1999)012<1577:TMDOMA>2.0.CO;2

18 Adams, D. K., and Comrie, A. C. (1997). The north American monsoon. Bulletin of the American Meteorological Society, 78(10), 2197–2214. DOI: https://doi.org/10.1175/1520-0477(1997)078<2197:TNAM>2.0.CO;2

month. On the Yucatán Peninsula, Campeche observed the region's driest monthly mean in March (21.15 mm), but Yucatán observed the region's driest annual totals (1,099.75 mm), roughly half that of Tabasco. Midsummer precipitation minimums (see **Figure 2b**) explain part of this pattern on the Caribbean coast.

States along Mexico's southern Pacific coast contain the greatest topographic and climatic diversity. All states in the south encompass mountains and valleys (typically subtropical or temperate) and lower-lying coasts (typically more tropical), resulting in wider temperature ranges than along the Gulf and Caribbean coasts. Colima, which has the greatest proportion of its area in the coastal lowlands, observed the region's warmest monthly mean in June (27.39°C). Jalisco, with higher latitudes and altitudes, observed the region's coolest month in January (16.94°C) with an average temperature range of 8°C–26°C. The onset of the wet season, regulated by the ITCZ, begins in May and lasts longer in Mexico's southeast. For this reason, Chiapas observed the highest annual precipitation (2,011.47 mm) and monthly precipitation in September (353.05 mm). Colima observed the region's driest monthly mean in April (1.51 mm), while Jalisco observed the region's driest annual precipitation (883.72 mm) – less than half that of Chiapas – partly due to its distance from the Equator and domain extending into the drier Central Plateau.

Central Mexico, which contains the highest altitudes, observed the coolest temperatures nationally and received less annual rainfall than along the southern Pacific coast. Morelos, situated at a lower elevation closer to the coast, observed the region's warmest monthly mean temperature in May (24.87°C) and driest monthly mean precipitation in February (2.07 mm). Guanajuato, situated at a higher latitude further inland, observed the region's driest annual precipitation totals (613.10 mm). High-altitude Ciudad de México (Mexico City) observed the coolest monthly mean temperature (10.49°C in December) and coolest annual mean temperature nationally (13.59°C). In December, its average temperature range extended from 1°C–20°C, the widest in the region. Hidalgo, closest to moisture from the Gulf of Mexico, observed the region's wettest monthly mean in September (232.52 mm), while Ciudad de México observed the wettest annual precipitation volumes in the region (1,081.12 mm). However, annual precipitation totals varied minimally between states compared to other regions.

Northern Mexico, situated on the Mexican Plateau above the Tropic of Cancer, observed the greatest annual temperature variation in the country and low precipitation amounts. Tamaulipas on the northern Gulf coast with lower elevations observed the region's warmest monthly mean temperature in June (28.83°C), wettest monthly mean precipitation (153.90 mm in September), and wettest annual mean precipitation (665.06 mm). The region's northernmost state of Chihuahua (see **Figure 2c**) observed the region's coolest monthly mean temperature in December (9.24°C with an average temperature range of 0°C–19°C), while the interior state of Zacatecas observed the region's coolest mean annual temperature (17.68°C). At the same time, however, all states experienced a peak monthly maximum temperature in the summer of approximately 30°C or greater. Durango observed the region's driest monthly mean temperature in April (4.10 mm), while Coahuila observed the region's driest annual mean precipitation totals (330.50 mm), roughly half that of Tamaulipas.

Northwest Mexico, influenced by the North American Monsoon, observed the shortest rainy season and a relatively wide range of seasonal temperatures. Sonora, containing the Sonora Desert, observed the country's hottest monthly mean temperature in July (30.01°C), while more tropical Sinaloa observed the region's warmest annual mean temperature (24.51°C). All states experienced a peak monthly maximum temperature in the summer greater than 32°C. Since the rainy season starts later in July or August further north, Nayarit in the south observed the region's wettest monthly precipitation (276.88 mm in August) and wettest annual totals (1,105.39 mm). The northernmost state of Baja California, which is influenced by the cold California current and experiences a dry summer and wet winter (see **Figure 2d**), observed the region's coolest monthly mean temperature (13.15°C), as well as driest annual mean precipitation in the country (161.44 mm), nearly one-tenth that of Nayarit just outside of the Gulf of California. Baja California Sur observed the country's driest monthly mean precipitation in May (1.18 mm), though every state in the northwest received roughly equivalent annual precipitation minimums.

Mexico's interannual rainfall variability is further influenced by ENSO. During El Niño, the ITCZ remains further south, resulting in wetter westerly-driven winter months in the far north, but drier summer nationwide.[19] During La Niña, tropical regions become wetter and tend to accompany an increase in tropical cyclone activity in the Caribbean. Tropical cyclones (classified as hurricanes if they attain maximum sustained winds greater than 74 mph) also influence interannual precipitation variability between May and November along Mexico's Pacific coast, accounting for significant portions of annual average rainfall and posing frequent risks to settlements and infrastructure. The ENSO phenomenon and tropical cyclone risks in Mexico are discussed further in the last section of this profile on climate-related hazards.

TABLE 2. Observed Temperature and Precipitation Trends for 1991–2020 Climatology Across Mexico's States

Climatic-Topographic Region and State	Observed Warmest (Top) and Coolest (Bottom) Months by Mean Temp.	Duration of Wet and Dry Seasons	Observed Wettest and Driest Months per Season	Observed Annual Precip.
Northwest Sierras and Coastal Lowlands (Subtropical and Temperate Dry)				
Baja California	Aug: 26.11°C (18.43°C, 33.84°C)	W: Dec–Mar	W: Feb (30.32 mm)	**161.44 mm**
	Jan: 13.15°C (6.00°C, 20.35°C)	D: Apr–Nov	D: June (1.33 mm)	
Sonora	**July: 30.01°C** (23.16°C, 36.90°C)	W: July–Sept	W: Aug (93.78 mm)	355.13 mm
	Jan: 14.52°C (6.62°C, 22.46°C)	D: Oct–June	D: May (2.51 mm)	
Northwest Sierras and Coastal Lowlands (Subtropical Dry)				
Baja California Sur	Aug: 28.29°C (21.60°C, 35.03°C)	W: Aug–Sept	W: Sept (59.97 mm)	182.72 mm
	Jan: 17.52°C (10.56°C, 24.53°C)	D: Oct–July	**D: May (1.18 mm)**	
Northwest Sierras and Coastal Lowlands (Tropical and Subtropical Dry)				
Sinaloa	June: 29.30°C (22.85°C, 35.79°C)	W: July–Sept	W: Aug (201.22 mm)	697.76 mm
	Jan: 18.86°C (11.36°C, 26.41°C)	D: Oct–June	D: Apr (1.32 mm)	

19 Magaña, V., and Diaz, S. (2022). Inter ocean basin moisture fluxes and the onset of the summer rainy season over southern Mexico. Frontiers in Climate, 4, 1037350. DOI: https://doi.org/10.3389/fclim.2022.1037350

TABLE 2. Observed Temperature and Precipitation Trends for 1991–2020 Climatology Across Mexico's States (*Continued*)

Climatic-Topographic Region and State	Observed Warmest (Top) and Coolest (Bottom) Months by Mean Temp.	Duration of Wet and Dry Seasons	Observed Wettest and Driest Months per Season	Observed Annual Precip.
Northwest Sierras and Coastal Lowlands (Tropical and Subtropical Moist, Subtropical Dry)				
Nayarit	June: 26.03°C (19.86°C, 32.25°C)	W: June–Oct	**W: Aug (276.88 mm)**	**1,105.39 mm**
	Jan: 18.83°C (11.09°C, 26.62°C)	D: Nov–May	D: Apr (2.62 mm)	
Northern Sierras and Coastal Lowlands (Subtropical Dry)				
Tamaulipas	**June: 28.83°C** (22.35°C, 35.36°C)	W: May–Oct	**W: Sept (153.90 mm)**	**665.06 mm**
	Jan: 16.56°C (9.56°C, 23.62°C)	D: Nov–Apr	D: Feb (16.39 mm)	
Northern Sierras, Plateau, Coastal Lowlands (Subtropical and Temperate Dry)				
Coahuila	June: 27.76°C (20.08°C, 35.48°C)	W: May–Oct	W: Sept (61.03 mm)	**330.50 mm**
	Jan: 11.92°C (3.73°C, 20.16°C)	D: Nov–Apr	D: Feb (11.06 mm)	
Nuevo León	July: 27.54°C (20.46°C, 34.66°C)	W: May–Oct	W: Sept (114.17 mm)	496.02 mm
	Jan: 14.09°C (6.85°C, 21.37°C)	D: Nov–Apr	D: Dec (14.82 mm)	
Northern Sierras and Plateau (Subtropical and Temperate Dry, Temperate Moist)				
Durango	June: 23.42°C (15.20°C, 31.70°C)	W: June–Oct	W: July (133.34 mm)	578.40 mm
	Jan: 11.93°C (3.20°C, 20.71°C)	D: Nov–May	**D: Apr (4.10 mm)**	
Northern Sierras and Plateau (Subtropical and Temperate Dry)				
Chihuahua	June: 25.79°C (16.58°C, 35.05°C)	W: June–Sept	W: July (104.90 mm)	405.64 mm
	Dec: 9.24°C (0.39°C, 18.13°C)	D: Oct–May	D: Apr (5.05 mm)	
San Luis Potosí	June: 23.89°C (15.98°C, 31.85°C)	W: May–Oct	W: Sept (140.88 mm)	632.12 mm
	Dec: 15.23°C (7.13°C, 23.39°C)	D: Nov–Apr	D: Dec (11.88 mm)	

(*continues*)

TABLE 2. Observed Temperature and Precipitation Trends for 1991–2020 Climatology Across Mexico's States (*Continued*)

Climatic-Topographic Region and State	Observed Warmest (Top) and Coolest (Bottom) Months by Mean Temp.	Duration of Wet and Dry Seasons	Observed Wettest and Driest Months per Season	Observed Annual Precip.
Northern Sierras and Plateau (Temperate Dry)				
Zacatecas	June: 22.11°C (13.80°C, 30.46°C)	W: June–Oct	W: July (94.28 mm)	462.90 mm
	Jan: 12.50°C (3.23°C, 21.83°C)	D: Nov–May	D: Apr (6.58 mm)	
Aguascalientes	June: 22.02°C (14.26°C, 29.83°C)	W: June–Oct	W: July (108.28 mm)	512.10 mm
	Jan: 13.35°C (3.73°C, 23.02°C)	D: Nov–May	D: Apr (5.85 mm)	
Central Sierras and Plateau (Tropical and Subtropical Dry)				
Morelos	**May: 24.87°C** (16.17°C, 33.62°C)	W: May–Oct	W: Aug (207.19 mm)	984.48 mm
	Dec: 19.53°C (10.66°C, 28.44°C)	D: Nov–Apr	**D: Feb (2.07 mm)**	
Central Sierras and Plateau (Subtropical and Temperate Dry)				
Guanajuato	May: 21.97°C (13.06°C, 30.94°C)	W: May–Oct	W: July (133.14 mm)	**613.10 mm**
	Jan: 14.37°C (5.65°C, 23.14°C)	D: Nov–Apr	D: Feb (5.73 mm)	
Querétaro	May: 22.36°C (13.49°C, 31.27°C)	W: May–Oct	W: Sept (143.79 mm)	675.75 mm
	Jan: 14.98°C (6.52°C, 23.50°C)	D: Nov–Apr	D: Feb (6.80 mm)	
Puebla	May: 21.91°C (14.01°C, 29.86°C)	W: May–Oct	W: Sept (217.87 mm)	1,079.31 mm
	Jan: 16.08°C (7.98°C, 24.24°C)	D: Nov–Apr	D: Feb (13.12 mm)	
Central Sierras and Plateau (Subtropical Moist and Temperate Dry)				
Hidalgo	May: 20.96°C (12.43°C, 29.55°C)	W: June–Oct	**W: Sept (232.52 mm)**	1,064.68 mm
	Jan: 14.16°C (5.75°C, 22.61°C)	D: Nov–Apr	D: Dec (17.04 mm)	
México	May: 19.15°C (10.71°C, 27.65°C)	W: May–Oct	W: Aug (205.51 mm)	1,021.36 mm
	Dec: 13.66°C (5.13°C, 22.24°C)	D: Nov–Apr	D: Feb (5.22 mm)	

TABLE 2. Observed Temperature and Precipitation Trends for 1991–2020 Climatology Across Mexico's States (*Continued*)

Climatic-Topographic Region and State	Observed Warmest (Top) and Coolest (Bottom) Months by Mean Temp.	Duration of Wet and Dry Seasons	Observed Wettest and Driest Months per Season	Observed Annual Precip.
Central Sierras and Plateau (Temperate Dry)				
Ciudad de México (Mexico City)	May: 15.72°C (7.22°C, 24.27°C)	W: May–Oct	W: Aug (230.23 mm)	**1,081.12 mm**
	Dec: 10.49°C (1.53°C, 19.49°C)	D: Nov–Apr	D: Feb (5.18 mm)	
Tlaxcala	May: 17.44°C (9.23°C, 25.70°C)	W: May–Oct	W: Sept (153.01 mm)	825.76 mm
	Dec: 12.05°C (3.63°C, 20.53°C)	D: Nov–Apr	D: Feb (6.73 mm)	
Southern Sierras, Plateau, and Coastal Lowlands (Tropical Dry and Moist, Subtropical Dry and Moist, Temperate Dry and Moist)				
Jalisco	June: 23.94°C (16.99°C, 30.95°C)	W: June–Oct	W: July (200.09 mm)	**883.72 mm**
	Jan: 16.94°C (8.03°C, 25.91°C)	D: Nov–May	D: Apr (3.47mm)	
Southern Sierras, Plateau, and Coastal Lowlands (Tropical Dry, Subtropical Dry and Moist, Temperate Dry and Moist)				
Michoacán	May: 24.93°C (16.22°C, 33.68°C)	W: June–Oct	W: Sept (214.23 mm)	977.96 mm
	Jan: 19.09°C (10.25°C, 27.99°C)	D: Nov–May	D: Feb (4.35 mm)	
Southern Sierras and Coastal Lowlands (Tropical Dry and Subtropical Moist)				
Colima	**June: 27.39°C** (21.74°C, 33.09°C)	W: June–Oct	W: Sept (259.36 mm)	988.28 mm
	Jan: 22.68°C (14.79°C, 30.64°C)	D: Nov–May	**D: Apr (1.51 mm)**	
Southern Sierras and Coastal Lowlands (Tropical Dry and Moist, Subtropical Dry and Moist, Temperate Moist)				
Guerrero	May: 26.79°C (19.67°C, 33.94°C)	W: May–Oct	W: Sept (269.30 mm)	1,136.95 mm
	Jan: 22.54°C (14.99°C, 30.13°C)	D: Nov–Apr	D: Feb (1.90 mm)	
Southern Sierras and Coastal Lowlands (Tropical Dry and Moist, Subtropical Dry and Moist, Temperate Dry and Moist)				
Oaxaca	May: 24.35°C (17.10°C, 31.65°C)	W: May–Oct	W: Sept (252.59 mm)	1,346.09 mm
	Dec: 19.80°C (12.26°C, 27.38°C)	D: Nov–Apr	D: Feb (10.24 mm)	

(*continues*)

TABLE 2. Observed Temperature and Precipitation Trends for 1991–2020 Climatology Across Mexico's States (*Continued*)

Climatic-Topographic Region and State	Observed Warmest (Top) and Coolest (Bottom) Months by Mean Temp.	Duration of Wet and Dry Seasons	Observed Wettest and Driest Months per Season	Observed Annual Precip.
Southern Sierras and Coastal Lowlands (Tropical, Subtropical, and Temperate Moist)				
Chiapas	May: 25.74°C (19.06°C, 32.47°C)	W: May–Oct	**W: Sept (353.05 mm)**	**2,011.47 mm**
	Jan: 21.68°C (14.97°C, 28.44°C)	D: Nov–Apr	D: Feb (33.49 mm)	
Eastern Coast (Tropical and Subtropical Moist)				
Veracruz	June: 27.61°C (22.21°C, 33.06°C)	W: June–Oct	W: Sept (345.74 mm)	1,753.41 mm
	Jan: 20.37°C (15.23°C, 25.57°C)	D: Dec–Apr	D: Feb (33.12 mm)	
Eastern Coast (Tropical Moist)				
Tabasco	**May: 29.40°C** (23.39°C, 35.46°C)	W: June–Nov	**W: Oct (406.03 mm)**	**2,300.54 mm**
	Jan: 23.76°C (18.92°C, 28.66°C)	D: Feb–Apr	D: Mar (50.95 mm)	
Quintana Roo	June: 28.12°C (23.10°C, 33.18°C)	W: May–Oct	W: Oct (206.79 mm)	1,324.16 mm
	Jan: 23.53°C (17.84°C, 29.28°C)	D: Dec–Apr	D: Mar (28.59 mm)	
Eastern Coast (Tropical Dry and Moist)				
Campeche	May: 28.96°C (22.47°C, 35.50°C)	W: May–Oct	W: Sept (223.90 mm)	1,344.82 mm
	Jan: 23.11°C (17.01°C, 29.27°C)	D: Dec–Apr	**D: Mar (21.15 mm)**	
Eastern Coast (Tropical Dry)				
Yucatán	May: 28.76°C (22.30°C, 35.27°C)	W: May–Oct	W: June (180.85 mm)	**1,099.75 mm**
	Jan: 23.48°C (17.38°C, 29.62°C)	D: Nov–Apr	D: Mar (23.16 mm)	

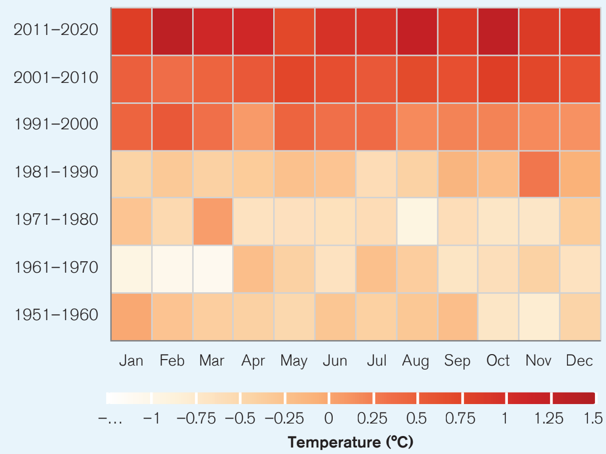
Climatic zones classified according to Sayre et al. and grouped by topo-geographic region (Northwest Mexico shaded light yellow, Northern Mexico shaded dark yellow, Central Mexico shaded dark green, Southern Mexico shaded purple, and Eastern Mexico shaded light green).[20] Each state's warmest month generally corresponds with the period around the onset of the ITCZ and the coolest month during the middle of the dry season. For the column listing mean monthly temperatures, the minimum (left) and maximum (right) temperatures are shown in parentheses. Precipitation regimes indicate wettest (W) and driest (D) months and are further interpreted in the text.

[20] Sayre, R., Karagulle, D., Frye, C., Boucher, T., Wolff, N. H., Breyer, S., et al. (2020). An assessment of the representation of ecosystems in global protected areas using new maps of World Climate Regions and World Ecosystems. Global Ecology and Conservation, 21, e00860. DOI: https://doi.org/10.1016/j.gecco.2019.e00860

Temperature

Between 1971 and 2020, Mexico's average mean temperature increased by 0.31°C per decade, with the greatest changes observed in the Northern Plateau region, especially during the summer months. Nationwide, average minimum temperatures increased 0.26°C per decade between 1971–2020, while average maximum temperatures increased 0.40°C per decade over the same period (**see Figure 3**). The northern state of Chihuahua recorded the highest annual average mean temperature increase per decade (0.47°C), minimum temperature increase per decade (0.40°C), and maximum temperature increase per decade (0.53°C). By comparison, the lowest significant temperature increases over this period occurred along the Pacific coast. Sinaloa and Nayarit observed a 0.18°C mean increase per decade, Nayarit observed a 0.13°C minimum increase per decade, and Colima observed a 0.16°C maximum increase per decade. Summer months exhibited the greatest seasonal increase in temperature per decade, with maximum temperature changes greater than 0.50°C extending beyond the Northern Plateau to parts of the Central Plateau (including Mexico City) and interior Yucatán Peninsula. During summer months, Chihuahua recorded a minimum temperature increase of 0.54°C per decade and Coahuila recorded an average mean temperature increase of 0.58°C per decade, as well as an average maximum temperature increase of 0.68°C per decade. Average maximum temperature increases above 0.50°C per decade also extended to Sonora during spring and fall months and Ciudad de México during spring and winter months. In fact, during winter months, the capital observed a 0.59°C per decade maximum temperature increase and Campeche (interior Yucatán Peninsula) observed a 0.48°C per decade increase. This pattern illustrates the geographical expanse and seasonal duration across which maximum temperature increased.

FIGURE 3. Heatplot of Historically Observed Maximum Temperature Trend per Month Nationally, 1951–2020

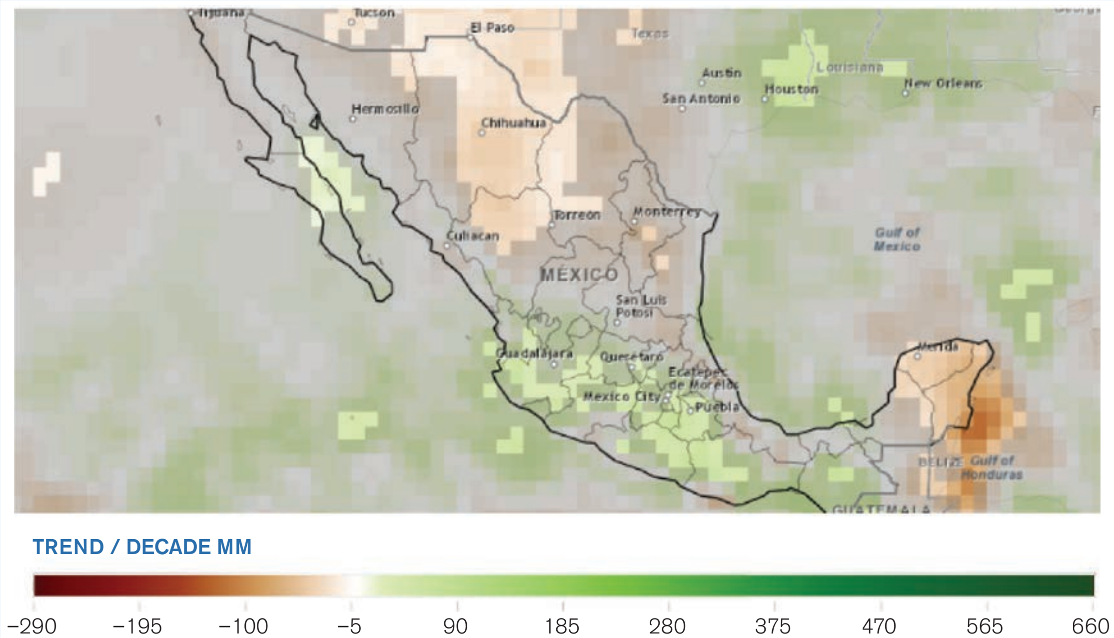


Note the sizable shift in maximum temperature year-round starting in the 1990s.

Precipitation

Over the 50-year period of 1971–2020, Mexico experienced significant decreases in precipitation per decade across the far Northern Plateau and Yucatán Peninsula, but significant precipitation increases along the Cordillera Neo-Volcánica, Sierra Madre del Sur, and central Gulf of California (**see Figure 4**). During the 1971–2020 climatology, the Yucatán Peninsula observed the largest total decreases in precipitation per decade in Quintana Roo (–55.39 mm) followed by Yucatán (–43.70 mm), with the strongest effects during the summer months. The Northern Plateau closest to the U.S. border also observed a significant but less drastic decline in precipitation per decade. In particular, Chihuahua observed a decline of –24.68 mm per decade with the strongest effects also occurring during summer months. By contrast, most of the Cordillera Neo-Volcánica and Sierra Madre del Sur observed significant precipitation increases over the same time period mostly during summer and fall months, with the greatest significant change occurring in Morelos (+56.31 mm per decade). During fall months,

FIGURE 4. Observed Precipitation Trend per Decade (1971–2020) Annually



Areas shaded gray indicate where a statistical significance of 95th percentile is not met. Note decreases in the far north and Yucatán Peninsula but increases along the central and southern Sierras as well as the central Gulf of California.

Baja California Sur observed a significant increase of 12.15 mm per decade and positive precipitation anomalies in other states such as Veracruz (28.64 mm per decade) were offset by negative anomalies during other seasons. The remaining regions in the North, Northwest, and Isthmus of Tehuantepec did not observe any significant change over the 50-year climatology (see **Figure 4**). Overall, there were no significant observed changes for the largest 1-day and 5-day precipitation events, highlighting the historical influence of interannual ENSO variability. However, the one exception was a small significant increase in the largest 5-day cumulative precipitation amounts in the central Gulf of California, which likely correspond with a wetter North American Monsoon.

PROJECTED CLIMATE

Data Overview

Modeled climate data is derived from CMIP6, the Coupled Model Intercomparison Project, Phase 6. The CMIP efforts are overseen by the World Climate Research Program, which supports the coordination for the production of global and regional climate model compilations that advance scientific understanding of the multi-scale dynamic interactions between the natural and social systems affecting climate. CMIP6 is the foundational data used to present global climate change projections presented in the Sixth Assessment Report (AR6) of the Intergovernmental

Panel on Climate Change (IPCC). CMIP6 relies on the Shared Socioeconomic Pathways (SSPs), which represent possible societal development and policy scenarios for meeting designated radiative forcing (W/m^2) by the end of the century. Scenarios are used to represent the climate response to different plausible future societal development storylines and associated contrasting emission pathways to outline how future emissions and land use changes translate into responses in the climate system. Model-based, climate projection data is derived from the Coupled Model Inter-comparison Project-Phase 6 (CMIP6). CMIP is a standard framework for the analysis of coupled atmosphere-ocean general circulation models (GCMs) providing projections of future temperature and precipitation according to designated scenarios. CMIP6 projections are shown through five shared socio-economic pathway (SSP) scenarios defined by their total radiative forcing (a cumulative measure of GHG emissions from all sources) pathway and level by 2100. These represent possible future greenhouse gas concentration trajectories adopted by the IPCC.

The following assessment explores projected climate conditions and changes under multiple scenarios[21] for the near (the 2030s; 2020–2039) and medium term (2050s; 2040–2059) using data presented at a 0.25° × 0.25° (25km × 25km) resolution.[22] This risk profile focuses primarily on SSP3-7.0. Other SSPs are highlighted where appropriate given different trends and outlooks that should be noted. Projections for extreme precipitation events use data presented at a 1.00° × 1.00° (100km × 100km) resolution.[23]

Temperature

Under SSP3-7.0, Mexico's temperatures are projected to increase further (see Figure 5). Mean temperature nationwide increases 0.82°C (0.47°C, 10th percentile, 1.21°C, 90th percentile) from the historical reference period of 1995–2014 to 22.02°C (21.46°C, 22.62°C) for the period 2020–2039, and 1.63°C (1.20°C, 2.20°C) to 22.83°C (22.18°C, 23.64°C) for the period 2040–2059. Minimum temperature nationwide increases 0.80°C (0.48°C, 1.18°C) from the historical reference period to 15.98°C (15.44°C, 16.55°C) for the 2020–2039 period, and by an anomaly of approximately 1.56°C (1.14°C, 2.10°C) to 16.74°C (16.11°C, 17.54°C) for 2040–2059. Maximum temperature increases by an anomaly of 0.85°C (0.45°C, 1.26°C) to 28.06°C (27.39°C, 28.75°C) for the 2020–2039 period, and by an anomaly of 1.70°C (1.21°C, 2.36°C) to 28.92°C (28.16°C, 29.79°C) for 2040–2059. However, projected temperature changes under SSP2-4.5 and SSP1-2.6 are somewhat lower.[24] Under SSP3-7.0, the largest seasonal change occurs during spring months in the Northern and Central Plateaus, where Coahuila and Zacatecas' mean temperatures both increase 1.93°C from the reference period by midcentury, compared to 1.29°C in Baja California. Minimum and maximum temperatures increase homogeneously, but during spring months there is a large increase in maximum temperatures across the Northern and Central Plateaus. By midcentury under SSP3-7.0, Zacatecas is projected to observe a 2.06°C increase in its median maximum temperature during spring months compared to 1.28°C in Quintana Roo.

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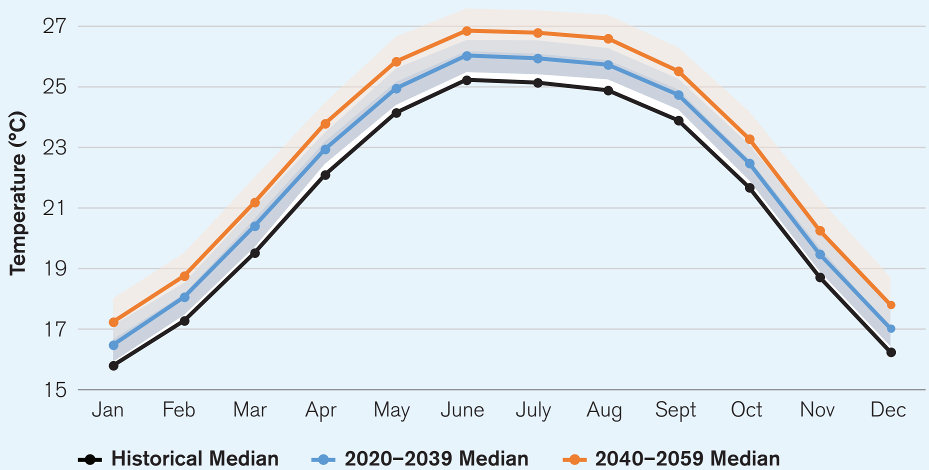
21 SSP3-7.0 represents a higher emissions scenario and is considered a more realistic worst-case scenario in which warming reaches ~3.5–4°C by 2100. When considering 'risk' it is most prudent to use higher scenarios in order to not dangerously under-estimate potential changes and risk conditions.

22 World Bank Climate Change Knowledge Portal (2023). Mexico Climate Projections. URL: https://climateknowledgeportal.worldbank.org/country/mexico/climate-data-projections

23 World Bank Climate Change Knowledge Portal (2023). Mexico Extreme Events. URL: https://climateknowledgeportal.worldbank.org/country/mexico/extremes

24 Under SSP1-2.6, minimum temperature nationwide only increases to 16.36°C (15.74°C, 17.02°C) and under SSP2-4.5, increases to 16.64°C (16.03°C, 17.29°C) by 2040–2059. Under SSP1-2.6, maximum temperature increases nationwide to 28.52°C (27.84°C, 29.25°C), and under SSP2-4.5, increases to 28.82°C (28.14°C, 29.56°C) by 2040–2059.

FIGURE 5. Projected Climatology of Mean Temperature Countrywide for 2020–2039 and 2040–2059 (Ref. Period 1995–2014) Under SSP3-7.0



Areas shaded yellow indicate 10th and 90th percentiles for 2040–2059, while areas shaded blue indicate 10th and 90th percentiles for 2020–2039. The projected climatology of mean temperature countrywide for each month (2040–2059 period) increases roughly two times the projected climatology for 2020–2039 above the reference period.

Projected mean temperatures under SSP3-7.0 underscore how many states across the country are expected to endure conditions characteristic of different climatic zones by midcentury (**see Table 3**). Tlaxcala in the *tierra fría* observes future median temperatures outside those characteristics of *tierra fría* elevations during the reference period, while Ciudad de México nearly reaches this threshold. Several states with subtropical temperatures on average (Sinaloa, Tamaulipas, and Guerrero) reach mean annual temperatures above 25°C by midcentury, characteristic of *tierra caliente* elevations. Many states in the Northern and Central Plateau (Chihuahua, Durango, Zacatecas, Aguascalientes, and Hidalgo) exceed mean annual temperatures characteristic of *tierra templada* elevations above 18°C during 2020–2039. Most of the remaining states in northern and central Mexico meanwhile are projected to observe mean annual temperature increases outside of the *tierra templada* range (~20°C) by midcentury. Notably, even under the lower-emission SSP1-2.6 scenario, only Tlaxcala, Tamaulipas, Guerrero, Querétaro, and Guanajuato's mean temperatures do not exceed the same thresholds that SSP3-7.0 does by midcentury.

Mexico is projected to experience spatially and seasonally variegated shifts in hotter conditions by midcentury. Higher atmospheric moisture content – during the summer and fall months nationwide, and along the eastern coast annually – makes the number of days surpassing the Heat Index >35°C a key risk factor in some states for the 2040–2059 climatology. The states with the greatest annual number of high Heat Index days projected by midcentury include Tabasco with 140.78 days (97.01 days, 176.15 days), Campeche with 118.94 days (72.81 days, 168.11 days), and Yucatán with 106.19 days (57.75 days, 153.34 days).

Heat-related risks can be compounded when considering both day temperature conditions and night temperature conditions. On nights temperatures do not go below 20°C, the human body reaches a biophysiological threshold where it cannot adequately cool down to achieve restorative sleep. The number of tropical nights with a minimum temperature >20°C (**see Table 4**) increases annually by roughly a month nationally, with the highest increases in

TABLE 3. Projected Annual Mean Temperatures in High-Elevation States for 2020–2039 and 2040–2059 (from Ref. Period 1995–2014) Under SSP3-7.0

State (Region)	Mean Annual Temperature 2020–2039	Mean Annual Temperature 2040–2059
Mexico (National)	22.02°C (21.46°C, 22.62°C)	22.83°C (22.18°C, 23.64°C)
Baja California (Northwest)	21.05°C (20.43°C, 21.83°C)	21.81°C (21.15°C, 22.74°C)
Sonora (Northwest)	23.14°C (22.46°C, 23.83°C)	24.04°C (23.32°C, 24.84°C)
Baja California Sur (Northwest)	23.59°C (23.10°C, 24.19°C)	24.27°C (23.70°C, 25.02°C)
Sinaloa (Northwest)	24.72°C (24.26°C, 25.23°C)	**25.50°C** (25.00°C, 26.16°C)
Nayarit (Northwest)	23.29°C (22.91°C, 23.85°C)	24.00°C (23.56°C, 24.83°C)
Tamaulipas (North)	24.51°C (23.89°C, 25.14°C)	**25.28°C** (24.60°C, 26.16°C)
Coahuila (North)	21.89°C (21.14°C, 22.59°C)	22.76°C (22.00°C, 23.65°C)
Nuevo León (North)	22.51°C (21.79°C, 23.22°C)	23.37°C (22.61°C, 24.26°C)
Durango (North)	**18.36°C** (17.81°C, 18.93°C)	**19.19°C** (18.53°C, 19.96°C)
Chihuahua (North)	**18.57°C** (17.88°C, 19.20°C)	**19.47°C** (18.71°C, 20.34°C)
San Luis Potosí (North)	20.59°C (20.01°C, 21.20°C)	21.42°C (20.75°C, 22.21°C)
Zacatecas (North)	**18.59°C** (18.06°C, 19.14°C)	**19.40°C** (18.78°C, 20.15°C)
Aguascalientes (North)	**18.69°C** (18.19°C, 19.20°C)	**19.48°C** (18.91°C, 20.16°C)
Morelos (Central)	22.56°C (22.08°C, 23.11°C)	23.37°C (22.80°C, 24.12°C)
Guanajuato (Central)	19.31°C (18.78°C, 19.83°C)	20.12°C (19.46°C, 20.80°C)
Querétaro (Central)	19.44°C (18.85°C, 19.98°C)	20.25°C (19.61°C, 20.98°C)
Puebla (Central)	19.80°C (19.29°C, 20.32°C)	20.59°C (20.00°C, 21.35°C)
Hidalgo (Central)	**18.50°C** (17.93°C, 19.05°C)	**19.30°C** (18.70°C, 20.07°C)
México (Central)	16.97°C (16.47°C, 17.50°C)	17.77°C (17.18°C, 18.51°C)
Ciudad de México (Central)	15.14°C (14.63°C, 15.67°C)	15.94°C (15.36°C, 16.69°C)
Tlaxcala (Central)	15.53°C (15.00°C, 16.02°C)	**16.32°C** (15.72°C, 17.07°C)

(*continues*)

TABLE 3. Projected Annual Mean Temperatures in High-Elevation States for 2020–2039 and 2040–2059 (from Ref. Period 1995–2014) Under SSP3-7.0 (*Continued*)

State (Region)	Mean Annual Temperature	
	2020–2039	2040–2059
Jalisco (Southern)	21.29°C (20.91°C, 21.84°C)	22.05°C (21.49°C, 22.80°C)
Michoacán (Southern)	22.31°C (21.91°C, 22.84°C)	23.07°C (22.50°C, 23.83°C)
Guerrero (Southern)	24.62°C (24.24°C, 25.15°C)	**25.35°C** (24.89°C, 26.14°C)
Oaxaca (Southern)	22.55°C (22.11°C, 23.09°C)	23.32°C (22.77°C, 24.15°C)
Chiapas (Southern)	23.78°C (23.36°C, 24.33°C)	24.57°C (24.00°C, 25.46°C)

10th percentile and 90th percentile values shown in parentheses. Median temperatures projected to increase above 16°C (upper threshold for *tierra fría*), 18°C (median annual temperature for *tierra templada*), and 25°C (lower threshold for *tierra caliente*) from the reference period are shaded orange and bolded. Other states with higher elevations not listed here (including Colima, Veracruz, and the rest of the Eastern region) already have temperatures characteristic of *tierra caliente* elevations. Note the states reaching thresholds for different climatic zones include Sinaloa, Tamaulipas, and Guerrero (*tierra caliente*), Tlaxcala (*tierra fría*), and five states in the Northern and Central Plateaus (*tierra templada*).

TABLE 4. Projected Tropical Night Anomalies for 2020–2039 and 2040–2059 (from the Ref. Period 1995–2014) Under SSP3-7.0 in States with the Greatest Change

State (Region)	2020–2039					2040–2059				
	Annual	Winter (DJF)	Spring (MAM)	Summer (JJA)	Fall (SON)	Annual	Winter (DJF)	Spring (MAM)	Summer (JJA)	Fall (SON)
High Heat Index Days (No. Days T-max >35°C)										
Nayarit (Northwest)	19.51 (10.64, 31.48)	1.69 (0.65, 3.18)	3.39 (1.35, 5.34)	8.28 (4.13, 13.86)	6.19 (2.80, 9.81)	39.93 (28.29, 61.06)	3.61 (2.48, 6.65)	6.88 (4.35, 11.32)	17.23 (11.25, 25.74)	12.30 (8.12, 18.87)
Morelos (Central)	30.15 (15.23, 45.44)	0.12 (0.01, 0.43)	9.96 (5.10, 14.45)	**13.75** (2.60, 19.97)	6.56 (4.08, 11.30)	57.51 (42.72, 84.66)	0.61 (0.09, 1.59)	18.19 (12.33, 26.32)	**25.44** (14.64, 34.85)	15.42 (10.42, 22.96)
Chiapas (South)	**32.95** (20.15, 47.76)	4.32 (2.19, 7.67)	8.88 (4.24, 13.82)	10.10 (5.71, 15.16)	9.12 (4.88, 14.56)	**62.25** (46.34, 85.88)	10.02 (6.02, 15.40)	16.39 (11.40, 23.93)	17.80 (11.69, 24.68)	17.40 (11.92, 24.66)
Tropical Nights (No. Nights T-min >26°C)										
Tamaulipas (North)	17.84 (6.72, 27.60)	0.00 (0.00, 0.00)	1.96 (0.48, 5.03)	13.15 (4.81, 18.95)	2.26 (0.66, 4.94)	39.50 (20.80, 61.62)	0.00 (0.00, 0.01)	5.98 (2.75, 11.86)	27.95 (14.15, 38.98)	5.96 (3.02, 10.64)
Tabasco (East)	**31.71** (10.43, 55.92)	0.02 (0.00, 0.17)	9.34 (3.24, 17.62)	**16.62** (5.25, 30.66)	3.01 (0.80, 9.03)	**81.04** (47.87, 115.04)	0.19 (0.04, 0.72)	21.76 (14.14, 34.22)	**44.78** (23.91, 63.77)	11.74 (4.68, 23.95)
Campeche (East)	17.68 (4.33, 37.40)	0.04 (–0.01, 0.19)	5.65 (1.01, 11.94)	9.13 (1.73, 20.03)	2.02 (0.44, 5.83)	54.52 (28.26, 101.02)	0.21 (0.06, 0.69)	15.85 (9.06, 28.28)	30.00 (13.82, 52.17)	7.86 (2.77, 17.59)

10th percentile and 90th percentile values shown in parentheses. Bolded values highlight the highest seasonal and annual anomalies per metric. Largest anomalies (>50 days) are shaded orange and smallest relative anomalies from the reference period are shaded gray (<5 days). Note that the greatest anomalies for tropical nights with minimum temperatures >20°C tend to occur in states along the Pacific coast, while the greatest anomalies for tropical nights with minimum temperatures >26°C tend to occur in states along the Gulf and Caribbean coasts, though according to different seasonal distributions. See text for interpretation.

the southeast. Such tropical nights increase by more than 30 days annually in Chiapas by 2020–2039 and 62.25 (46.34, 85.88) nights by 2040–2059 under SSP3-7.0, with changes highest during the summer months. In states along the Gulf and Caribbean coasts, the number of tropical nights with a minimum temperature >26°C, an even higher threshold, increase the most during summer months by midcentury (2040–2059) compared to the historical reference period. Tabasco is projected to experience the largest annual increase of 31.71 (10.43, 55.92) nights by 2020–2039 and 81.04 (47.87, 115.04) nights by 2040–2059. The SSP3-7.0 scenario forecasts a higher number of tropical nights >20°C and >26°C by midcentury compared to the SSP1-2.6 and SSP2-4.5 scenarios. Projected anomalies for tropical nights, among other key metrics to monitor, are detailed for all of Mexico's states in **Table 5.**

TABLE 5. Key Projected Anomalies by State for 2040–2059 (Ref. Period 1995–2014) Under SSP3-7.0

Projected Anomalies for 2040–2059 Under SSP3-7.0 (Ref. Period 1995–2014)			
State	**Max. of Daily Max. Temp. Anomaly Annually**	**Summer Days (No. Days T-max >25 °C) Annually**	**Tropical Nights (No. Nights T-min >20°C) Annually**
Mexico (National)	1.90°C (0.71°C, 3.33°C)	34.53 (24.38, 48.32)	29.01 (19.58, 40.83)
Northwest			
Baja California	1.44°C (0.18°C, 2.80°C)	31.12 (20.07, 45.76)	32.01 (20.61, 47.32)
Sonora	**1.76°C** (0.61°C, 3.14°C)	24.82 (16.61, 38.00)	30.07 (20.98, 38.88)
Baja California Sur	1.58°C (0.59°C, 2.67°C)	**33.44** (21.83, 47.02)	28.74 (17.25, 40.84)
Sinaloa	1.54°C (0.18°C, 2.65°C)	18.91 (15.10, 24.49)	30.38 (20.78, 40.76)
Nayarit	1.68°C (0.87°C, 2.86°C)	23.37 (18.92, 28.79)	**39.93** (28.29, 61.06)
North			
Tamaulipas	2.09°C (0.57°C, 3.98°C)	25.50 (17.18, 34.66)	32.47 (21.10, 46.41)
Coahuila	2.27°C (0.98°C, 3.66°C)	30.89 (20.38, 43.78)	**39.82** (26.97, 52.34)
Nuevo León	**2.41°C** (1.11°C, 3.86°C)	33.21 (22.03, 44.09)	23.56 (15.83, 32.34)
Durango	2.05°C (1.04°C, 3.44°C)	51.50 (36.01, 70.18)	16.13 (10.28, 21.89)
Chihuahua	1.97°C (0.94°C, 3.50°C)	36.97 (24.91, 53.53)	25.65 (17.51, 34.76)
San Luis Potosí	2.03°C (0.55°C, 3.85°C)	49.50 (37.23, 67.42)	26.60 (16.21, 37.64)
Zacatecas	2.17°C (1.02°C, 3.57°C)	58.71 (45.80, 82.39)	6.05 (2.79, 10.52)
Aguascalientes	2.13°C (0.87°C, 4.11°C)	**65.77** (51.53, 91.73)	0.58 (0.00, 2.13)

(*continues*)

TABLE 5. Key Projected Anomalies by State for 2040–2059 (Ref. Period 1995–2014) Under SSP3-7.0 (*Continued*)

Projected Anomalies for 2040–2059 Under SSP3-7.0 (Ref. Period 1995–2014)			
State	Max. of Daily Max. Temp. Anomaly Annually	Summer Days (No. Days T-max >25 °C) Annually	Tropical Nights (No. Nights T-min >20°C) Annually
Central			
Morelos	2.01°C (0.71°C, 4.04°C)	28.47 (21.71, 44.26)	**57.51** (42.72, 84.66)
Guanajuato	**2.20°C** (0.58°C, 3.61°C)	67.23 (50.15, 87.88)	1.51 (0.32, 3.92)
Querétaro	**2.20°C** (0.44°C, 3.64°C)	**68.82** (50.80, 93.68)	13.74 (7.18, 21.43)
Puebla	1.90°C (0.65°C, 3.90°C)	45.36 (32.91, 66.21)	21.62 (14.75, 31.60)
Hidalgo	2.06°C (0.48°C, 3.93°C)	65.98 (48.63, 91.63)	12.06 (7.71, 17.46)
México	2.06°C (0.63°C, 3.97°C)	46.49 (32.08, 71.77)	6.88 (4.90, 10.58)
Ciudad de México	2.01°C (0.56°C, 3.95°C)	41.34 (27.40, 69.66)	0.00 (0.00, 0.00)
Tlaxcala	2.01°C (0.53°C, 3.93°C)	49.11 (30.95, 81.90)	0.00 (0.00, 0.00)
Southern			
Jalisco	1.85°C (0.86°C, 3.00°C)	**48.76** (37.73, 64.19)	16.99 (10.43, 31.93)
Michoacán	**1.87°C** (0.81°C, 3.04°C)	40.28 (27.46, 55.40)	29.01 (20.24, 44.82)
Colima	1.74°C (0.93°C, 2.45°C)	9.15 (6.43, 11.95)	43.36 (29.75, 63.53)
Guerrero	1.73°C (0.72°C, 2.99°C)	22.22 (16.64, 29.80)	53.05 (36.85, 80.51)
Oaxaca	1.78°C (0.66°C, 3.11°C)	47.00 (34.36, 64.77)	30.76 (21.77, 45.14)
Chiapas	1.66°C (0.59°C, 3.01°C)	34.71 (24.32, 47.47)	**62.25** (46.34, 85.88)
Eastern			
Veracruz	1.77°C (0.46°C, 3.47°C)	**26.85** (19.58, 36.56)	**37.78** (27.08, 51.12)
Tabasco	1.64°C (0.46°C, 2.87°C)	9.08 (6.44, 13.35)	28.00 (19.77, 35.99)
Quintana Roo	**1.84°C** (0.52°C, 3.26°C)	4.80 (2.87, 6.98)	28.67 (16.85, 39.08)
Campeche	1.80°C (0.33°C, 3.02°C)	2.69 (1.57, 4.34)	32.05 (21.19, 44.88)
Yucatán	1.61°C (0.41°C, 3.15°C)	2.45 (1.02, 4.67)	35.58 (22.26, 51.07)

10th percentile and 90th percentile values shown in parentheses. Largest anomalies (>50 days or >1.90°C) are shaded orange and smallest relative anomalies from the reference period are shaded gray. The largest anomaly in each region is bolded. Note that the maximum of daily maximum anomalies increase most in the North and Central Plateaus, tropical nights increase most along the southern coast, and summer day anomalies increase most in the mountains bounding the southern portion of the Northern Plateau and northern portion of the Central Plateau. See text for interpretation.

In the elevated Northern and Central Plateaus, summer days with a maximum temperature >25°C increase year-round, but each state has unique seasonal peaks. Querétaro in Central Mexico is projected to experience the highest annual increase of 68.82 (50.80, 93.68) summer days by 2040–2059 under SSP3-7.0, mostly during fall months. Guanajuato, Hidalgo, and Aguascalientes follow Querétaro with nearly equivalent annual medians. Single-day maximum of daily maximum temperatures also increase the highest annually in the Northern and Central Plateaus across seasons (except winter months) by median anomalies of at least 2°C from the reference period. The highest annual increase of 2.41°C (1.11°C, 3.86°C) from the reference period is projected in Nuevo León by midcentury. Most states south of the Tropic of Cancer experience an increase of close to or above 100 days on the Warm Spell Duration Index by midcentury according to SSP3-7.0,[25] with an increase of more than 164.39 days expected annually in Guerrero. However, the SSP1-2.6 scenario forecasts an increase of much fewer days annually (roughly 50–80-day anomalies) for the same regions. The greatest overall increases in extreme heat risk occur in areas with lower elevations in each region. For further detail on how Mexico's projected temperature changes under SSP3-7.0 compare to other scenarios, see the profile's Annex.

Precipitation

Projected precipitation patterns under SSP3-7.0 reflect regional shifts in seasonal onset and intensity by midcentury, but trend toward a nationwide annual decrease reflected more markedly by percentage change instead of volume. At the national level, annual precipitation totals decrease by a median of –4.65% (–15.84%, 6.98%) from the 1995–2014 reference period under SSP3-7.0 by midcentury. Detailed precipitation trends in each of the given regions are discussed in turn below. Some seasonal and regional precipitation trends, while present by midcentury, have wider probability distributions. Many of these trends also shift when compared to different climate change scenarios. Western coastal states are projected to experience the greatest precipitation percentage decline by midcentury while eastern states are projected to experience the greatest decline in volume by midcentury, though deviations from this pattern are noted. The timing and extent of extreme precipitation intensities vary by state.

The tropical eastern states are expected to observe an annual decrease in precipitation by 2040–2059 under SSP3-7.0 with relatively high certainty. All states in the region experience decreases in the summer months and all except for Quintana Roo experience significant percent decreases during winter and spring dry season months. Yucatán (**see Figure 6a**), the state with the driest annual observed precipitation in the region, is projected to experience its greatest monthly percent decrease of –24.11% (–47.97%, –1.99%) from the reference period during July by midcentury. SSP3-7.0 also predicts a monthly percent increase of +11.97% (–6.06%, +45.07%) in October, indicating a later potential shift in the timing and intensity of the wet season that is consistent across most regions nationally. Both scenarios SSP1-2.6 and SSP2-4.5 predict less annual drying than SSP3-7.0 along the Gulf and Caribbean coasts by midcentury.

25 This value indicates the number days with consecutive daily maximum temperatures greater than the 90th percentile of daily maximum temperature calculated over a five-day window annually. Warm Spell Duration Index projections use 1.00° × 1.00° (100km × 100km) data resolution.

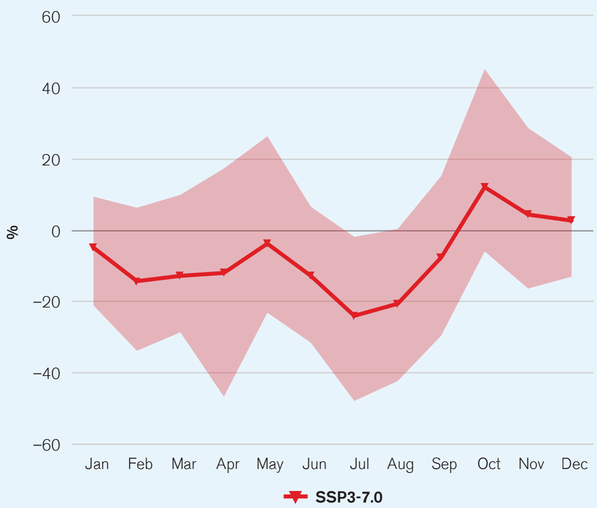
The southern Pacific coast is projected to experience the greatest anomalous percent decrease in precipitation for the 2040–2059 period under SSP3-7.0. Oaxaca and Chiapas are expected to adhere to a similar precipitation trend as states in the eastern region involving large precipitation percentage declines during summer months. SSP3-7.0 also predicts Chiapas will experience the largest annual precipitation decrease by volume of –71.73 mm (–197.50 mm, +88.75 mm) for the 2040–2059 period. However, unlike in the eastern region, states further west will experience greater percentage declines throughout their typical winter and spring dry seasons by midcentury. Colima (**see Figure 6b**), which features the region's driest observed monthly precipitation, is projected to experience the nation's greatest monthly percentage precipitation decline of –52.01% with a wide probability range (–109.29%, –7.75%) during February. This decrease far outpaces the percentage increase >10% predicted during the month of October at the end of Colima's wet season, an overall trend which the states of Jalisco and Michoacán also mirror. Similar to Eastern Mexico under both SSP1-2.6 and SSP2-4.5, the southern Pacific coast would likely observe a smaller decrease in precipitation annually by midcentury. However, under SSP3-7.0 and unlike most other states, Colima already realizes its peak February precipitation decline by the 2020-2039 period.

Central Mexico will experience more moderate precipitation percentage decreases year-round under SSP3-7.0 for the 2040–2059 period. All states in the region except Guanajuato, Querétaro, and México feature monthly percentage declines in precipitation >10% during midsummer months, similar to Eastern Mexico. However, the largest monthly percentage decreases occur throughout the winter and spring dry seasons. Guanajuato, which possesses the region's driest annual observed precipitation, contains Central Mexico's largest monthly percentage decrease of –29.78% (–56.06%, +10.21%) during February, with lower uncertainty ranges than both Yucatán and Colima. For 2040–2059 under SSP2-4.5, Central Mexico would experience slight annual precipitation percentage decreases but for the same period under SSP1-2.6, the region would experience virtually no percentage change in annual precipitation from the reference period.

Northern Mexico is projected to experience the largest regional percentage decrease in precipitation after the southern Pacific. Percentage declines occur throughout the dry season similar to Colima, with the region's largest monthly percentage decline in Aguascalientes during the month of February of –43.80% (–69.03%, +9.52%). SSP3-7.0 predicts a percentage increase >10% in the month of September for both Aguascalientes and San Luis Potosí near the end of their wet seasons. Though the large declines in winter and spring months offset the precipitation increase in late fall, the former have particularly high uncertainty on par with Colima's. Like Central Mexico, Northern Mexico would experience slight annual precipitation percentage decreases under SSP2-4.5, but for the same period under SSP1-2.6, the region would experience virtually no percentage change in annual precipitation from the reference period.

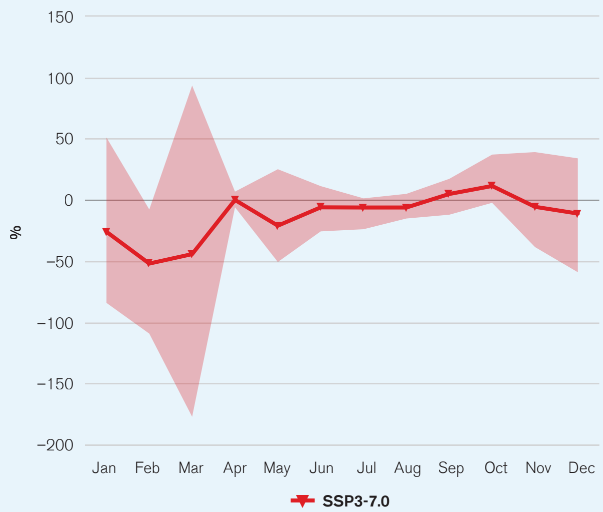
The region of Northwest Mexico experiences divergent precipitation trends by midcentury under SSP3-7.0. Nayarit, which features the region's wettest monthly and annual observed precipitation, possesses the nation's largest annual percentage decrease of –10.86% (–19.54%, +2.66%) with declines throughout the dry season similar to Jalisco and Colima. Its largest monthly percentage decline occurs in February of –43.64% (–77.80%, –1.74%), offsetting the percentage increase >10% during October at the end of its rainy season. By contrast, the Baja California Peninsula and Sonora are projected to experience marginally positive annual precipitation percentage increases. Sonora will likely record percentage increases during September and October over the same time period, indicating an extension of its wet season and more intense monsoon. Baja California Sur features the nation's largest monthly percentage increase of +31.79% (–53.09%, +137.25%) in October, indicating a shift in the end of the wet season but with very high uncertainty. Baja California (**see Figure 6c**) exhibits the nation's largest annual percentage increase

FIGURE 6A. Yucatán's (Eastern Mexico) Projected Precipitation Percent Change Anomaly for 2040–2059 (Ref. Period 1995–2014) Under SSP3-7.0



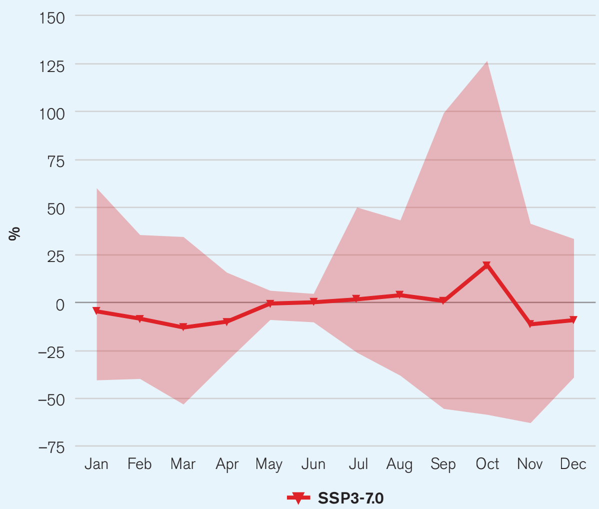
Area shaded red indicates 10th–90th percentiles. Note largest percentage decrease occurs over the summer months. See text for interpretation.

FIGURE 6B. Colima's (Southern Mexico) Projected Precipitation Percent Change Anomaly for 2040–2059 (Ref. Period 1995–2014) Under SSP3-7.0



Note the wider scale of percentage anomalies on the y-axis and the largest percentage decrease occurs in late winter and early spring. See text for interpretation.

FIGURE 6C. Baja California (Northwest Mexico) Projected Precipitation Percent Change Anomaly for 2040–2059 (Ref. Period 1995–2014) Under SSP3-7.0

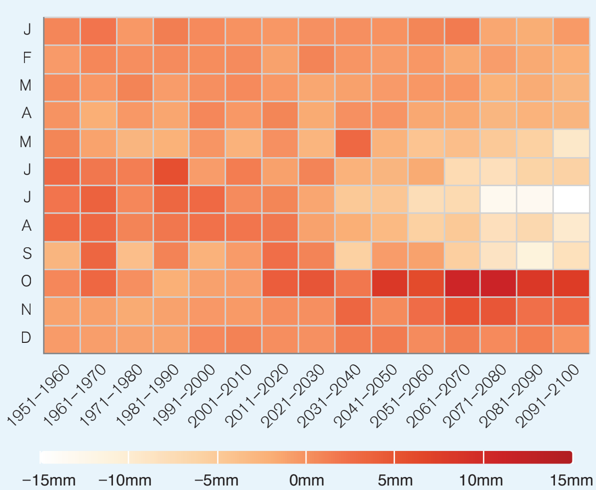


Note the wide but largely positive scale of percentage anomalies on the y-axis and the largest percentage increase in October. See text for interpretation.

of +2.64% (–18.47%, +21.13%) with otherwise regionally similar precipitation patterns. However, because of its unique precipitation distribution, SSP3-7.0 predicts a more prolonged or earlier shift in its dry season coupled with a greater potential monsoonal influence in the fall. Under both SSP1-2.6 and SSP2-4.5 for midcentury, the percentage precipitation decreases in Nayarit and Sinaloa are more moderate while the slight annual percentage increases for the rest of the Northwest region remain unchanged.

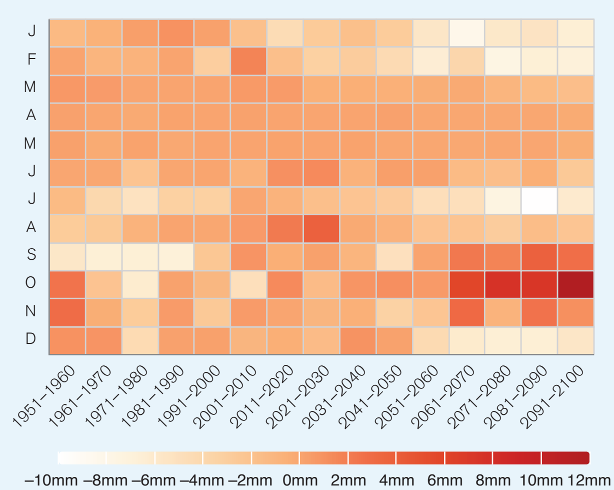
Mexico's future precipitation intensities, measured by average largest 5-day cumulative anomalies, vary by state and month but increase nationally by a median of 10.59 mm (–56.93 mm, +73.90 mm) by midcentury. Precipitation intensities increase 33.64 mm (–51.21 mm, 124.49 mm) in Chiapas (South) by midcentury, the most annually under SSP3-7.0. But while its precipitation intensity increases uniformly year-round, other states such as Tlaxcala (Central) have a peak during the June wet season and a large dip during the December dry season, amounting to virtually no net change annually. Campeche's (East, **see Figure 7a**) precipitation intensities counterintuitively increase most during the dry season month of December by 11.95 mm (–48.10 mm, 68.82 mm) but remain relatively unchanged for other months. By comparison, Sinaloa (Northwest, **Figure 7b**) exhibits little change in year-round intensity. Ultimately, both long-term precipitation percentage changes and intensities depend on interannual ENSO patterns. In addition, while maximum consecutive dry days do not substantively increase by midcentury under SSP3-7.0, the propensity for drought events remains high because of precipitation declines and interannual cycles. Both of these subjects are discussed further in the section on climate-related hazards and Mexico's projected precipitation changes under different scenarios are discussed further in the profile's Annex.

FIGURE 7A. Campeche's (Eastern Mexico) Projected Average Largest 5-Day Cumulative Precipitation Anomaly (Ref. Period 1995–2014) Under SSP3-7.0



Note by 2040–2059 (x-axis), a peak increase in intensity occurs during the dry season month of December, with a shift during the end of the wet season in October only toward the end of the century.

FIGURE 7B. Sinaloa's (Northwest Mexico) Projected Average Largest 5-Day Cumulative Precipitation Anomaly (Ref. Period 1995–2014) Under SSP3-7.0

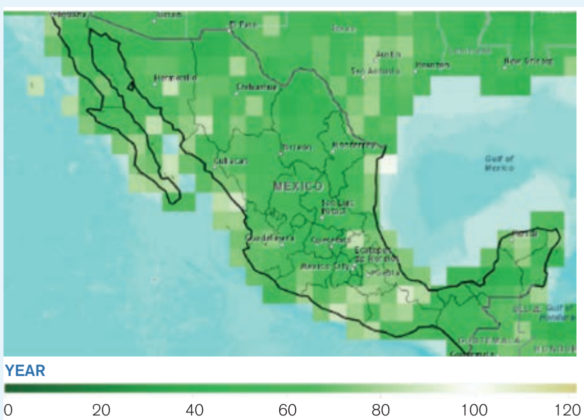


Note by 2040–2059 (x-axis), virtually no monthly change in intensity occurs until toward the end of the century.

Extreme Precipitation Events

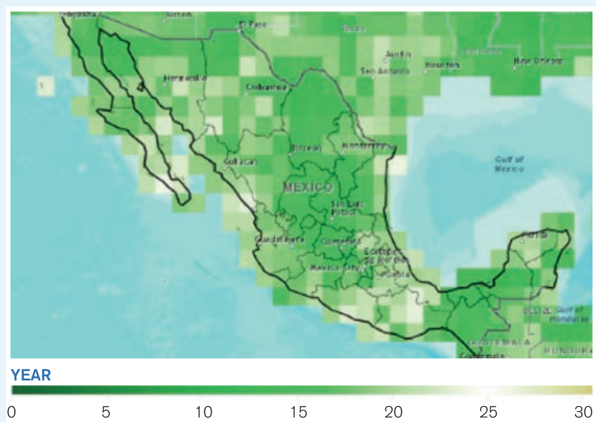
By midcentury, Mexico is likely to more frequently experience extreme precipitation event occurrence. For the projected period of 2035–2064, the largest 1-day precipitation amounts associated with 100-year historical return periods will be nearly two times more likely or more to occur in parts of the Central Plateau and Gulf coast (**see Figure 8a**). The greatest change in future return periods is projected for Campeche (53.18 years), Tabasco (53.17 years), and Querétaro (51.66 years). However, the rate of change is lower for 25-year and 50-year events, and less than 1.5 times more likely for 10-year events across the country. While the projected future return periods for 25-year events significantly shift for the same regions (15.24 years for Tabasco and 15.50 years for both Campeche and Querétaro), the future return periods for states in the Northwest and Isthmus of Tehuantepec change very little (remain >20 years) by midcentury (**see Figure 8b**). SSP1-2.6 and SSP2-4.5 do not forecast extreme event frequencies at significantly different rates than SSP3-7.0 for 2035–2064. More frequently occurring extreme precipitation events underscore future health risks related to flood impacts, agricultural yields, disease ranges, and critical infrastructure, including for water, sanitation, and hygiene.

FIGURE 8A. Future Return Period of Largest 1-Day Precipitation, 100-Year Event Under SSP3-7.0 (2035–2064, Center 2050)



Note the greatest change in future return periods projected for the Central and Northern Plateaus and parts of southeast Mexico.

FIGURE 8B. Future Return Period of Largest 1-Day Precipitation, 25-Year Event Under SSP3-7.0 (2035–2064, Center 2050)



Note the minimal change in future return periods projected for areas of Northwest Mexico and the Isthmus of Tehuantepec.

Between 1970 and 2009, climate-related natural hazards impacted approximately 60 million people in Mexico and averaged hundreds of millions of dollars ($U.S.) per year.[26] In fact, three or more hazards related to extreme temperature, precipitation, coastal, or seismic risks threaten roughly one-third of the country's GDP. Rising temperatures spurred a multifold increase in electricity demands for cooling since 1990 and increased heat-related deaths in Mexico by 57% between 2000–2004 and 2018.[27] Higher temperatures will likely result in a generalized increase in fire weather days, an expansion of vector-borne disease risk by midcentury, and greater strain on water resources, resulting in significant economic losses for sectors such as agriculture. At the same time, climate change will increase the likelihood of intense rainfall and flooding, leading to greater risks of landslides and mudslides disproportionately affecting low-income populations residing on marginal land. According to the national government's most recent (2021) multi-hazard climate risk assessment,[28] the states with the greatest number of highest-risk municipalities are Oaxaca followed by Michoacán, México, and Jalisco. Past and future impacts associated with each of Mexico's notable hazards are discussed below.

Sea Level Rise and Sea Surface Temperature

Mexico's observed sea surface temperatures reflect varying rates of change between and within its Pacific and Atlantic coasts that correlate with interannual and decadal climate patterns. Mexico's southern Pacific coast from Chiapas to Michoacán exhibit mean annual sea surface temperatures above 28.5°C that characterize the marine area known as the Eastern Pacific Warm Pool.[29] Wind-driven coastal upwelling in the Gulf of Tehuantepec (eastern coast of Oaxaca) produces relatively lower seasonal sea surface temperatures in this region. Further north, the mouth of the Gulf of California (near Mazatlán, Sinaloa) serves as a subtropical transition zone with a mean annual sea surface temperature close to 26°C. Lower seasonal temperatures occur off the coast of Cabo Corrientes (Jalisco) in this region, another important site of upwelling. Mean annual temperatures decline in the relatively shallow northern third of Gulf of California to below 24°C. By comparison, mean annual sea surface temperature drops from 24°C at the tip of the Baja California Peninsula near Cabo San Lucas (Baja California Sur) to less than 18°C off the coast of Tijuana (Baja California) due to the influence of the cold California Current. Mean annual surface temperatures on Mexico's eastern coast generally remain lower than 28.5°C, especially due to wind-driven seasonal upwelling in the Bay of Campeche and the northern Yucatán Peninsula.[30]

Annual sea surface temperature anomalies displayed differing regional trends over the most recent climatology (1991–2020).[31] Temperatures off the Pacific coast of the Baja California Peninsula displayed a relatively neutral

[26] World Bank (2013). Strengthening disaster risk management in Mexico. URL: https://www.worldbank.org/en/results/2013/09/04/disaster-risk-management-mexico
[27] CMCC (2021). G20 Climate Risk Atlas: Mexico. URL: https://files.cmcc.it/g20climaterisks/Mexico.pdf
[28] INECC (2021). Municipios Vulnerables al Cambio Climático con base en los resultados del Atlas Nacional de Vulnerabilidad al Cambio Climático. URL: https://atlasvulnerabilidad.inecc.gob.mx/conten_intro/Mpos_Vulnerables_priorizacion_ANVCC.pdf
[29] Flores-Morales, A. L., Pares-Sierra, A., and Marinone, S. G. (2009). Factors that modulate the seasonal variability of the sea surface temperature of the Eastern Tropical Pacific. Geofísica internacional, 48(3), 337–349. URL: https://www.scielo.org.mx/scielo.php?pid=S0016-71692009000300007&script=sci_arttext&tlng=en
[30] Zavala-Hidalgo, J., Gallegos-García, A., Martínez-López, B., Morey, S. L., and O'Brien, J. J. (2006). Seasonal upwelling on the western and southern shelves of the Gulf of Mexico. Ocean dynamics, 56, 333–338. DOI: https://doi.org/10.1007/s10236-006-0072-3
[31] CMCC (2021). G20 Climate Risk Atlas: Mexico. URL: https://files.cmcc.it/g20climaterisks/Mexico.pdf

temperature trend for the latest 30-year climatology but experienced the greatest rate of warming (>0.2°C per decade) off the northernmost coast of Baja California state. The Gulf of California lacked a significant long-term historical trend,[32] but experienced a small increase (<0.2°C per decade) for the most recent climatology. Temperature trends between Mexico's Gulf of California and the Gulf of Tehuantepec historically exhibited periods of interannual cooling,[33] but between 1991–2020 warmed close to 0.2°C per decade. The Gulf of Tehuantepec (east coast of Oaxaca) meanwhile displayed a longer-term neutral temperature trend. The western Gulf of Mexico and northwest Caribbean Sea consistently increased over the latest 30-year climatology by 0.2°C per decade or greater, except for small areas known for coastal upwelling. While decadal sea surface temperatures off Mexico's eastern coast correlate with the Atlantic Multidecadal Oscillation (AMO), interannual variations off Mexico's western coast (the East Pacific) correlate with El Niño-Southern Oscillation (ENSO), one of the primary drivers of climate variability nationwide.[34] ENSO's phases and broader effects are explored in the next subsection.

Sea level rise and coastal inundation will increasingly threaten Mexico's coastal zones by the end of the century, particularly along the Gulf of Mexico and Caribbean Sea. Mexico's vast coastline extends 23,761 km and houses more than half of the country's population in cities such as Tijuana, Veracruz, Cancún, and Acapulco.[35] Northwest Mexico, including the Gulf of California, is projected to experience relatively low rates of sea level rise compared to other parts of the country. Under SSP3-7.0 (**see Table 6**), Ensenada (Baja California) has the slowest increase of 0.19 m (0.14 m, 0.26 m) by 2050 and 0.60 m (0.44 m, 0.86 m) by 2100 above the 1995–2014 historical baseline. The highest projected increase nationally occurs along Mexico's southern Pacific coast at Acapulco (Guerrero), increasing 0.44 m (0.39 m, 0.51 m) by 2050 and 1.16 m (0.99 m, 1.42 m) by 2100.[36] Compared to the rocky Pacific coast, Mexico's sandy and low-lying eastern coast faces greater overall risks. There, the highest projected sea level rise is expected along the Caribbean Sea (Quintana Roo), increasing 0.40 m (0.30 m, 0.51 m) by 2050 and 1.05 m (0.81 m, 1.35 m) by 2100. The degradation and potential loss of wetland, mangrove, and beach and dune ecosystems due to sea level rise would cost an estimated USD$6 billion annually.[37] This would disproportionately impact fisheries in Baja California Sur, Sinaloa, and Campeche, as well as states economically dependent on tourism such as Quintana Roo. Sea level rise additionally concerns Manzanillo (Colima), Mexico's busiest port with access to Mexico City.[38] A high risk of coastal flooding, defined as potentially damaging waves at least once in the next 10 years according to the Global Facility for Disaster Risk Reduction (GFDRR), threatens all states in northwest Mexico (except Nayarit), Campeche, and Quintana Roo.[39]

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[32] Lluch-Cota, S. E., Tripp-Valdéz, M., Lluch-Cota, D. B., Lluch-Belda, D., Verbesselt, J., Herrera-Cervantes, H., and Bautista-Romero, J. J. (2013). Recent trends in sea surface temperature off Mexico. Atmósfera, 26(4), 537–546. DOI: https://doi.org/10.1016/S0187-6236(13)71094-4

[33] Lluch-Cota, S. E., Tripp-Valdéz, M., Lluch-Cota, D. B., Lluch-Belda, D., Verbesselt, J., Herrera-Cervantes, H., and Bautista-Romero, J. J. (2013). Recent trends in sea surface temperature off Mexico. Atmósfera, 26(4), 537–546. DOI: https://doi.org/10.1016/S0187-6236(13)71094-4

[34] Lluch-Cota, S. E., Tripp-Valdéz, M., Lluch-Cota, D. B., Lluch-Belda, D., Verbesselt, J., Herrera-Cervantes, H., and Bautista-Romero, J. J. (2013). Recent trends in sea surface temperature off Mexico. Atmósfera, 26(4), 537–546. DOI: https://doi.org/10.1016/S0187-6236(13)71094-4

[35] CMCC (2021). G20 Climate Risk Atlas: Mexico. URL: https://files.cmcc.it/g20climaterisks/Mexico.pdf

[36] NASA (2023). Sea Level Projection Tool. URL: https://sealevel.nasa.gov/ipcc-ar6-sea-level-projection-tool

[37] Fernández-Díaz, V. Z., Canul Turriza, R. A., Kuc Castilla, A., and Hinojosa-Huerta, O. (2022). Loss of coastal ecosystem services in Mexico: An approach to economic valuation in the face of sea level rise. Frontiers in Marine Science, 9, 898904. DOI: https://doi.org/10.3389/fmars.2022.898904

[38] USAID (2017). Mexico: Climate Risk Profile. URL: https://www.climatelinks.org/sites/default/files/asset/document/2017_USAID_Climate%20Change%20Risk%20Profile_Mexico.pdf

[39] GFDRR (2020). Mexico. URL: https://thinkhazard.org/en/report/162-mexico

TABLE 6. Projected Sea Level Rise Along Mexico's Coasts in Meters by 2050 and 2100 Under SSP3-7.0 (Ref. Period 1995–2014)[40]

City (State – Body of Water)	2050 (in m)	2100 (in m)
Tijuana* (Baja California – Pacific)	0.21 (0.15, 0.29)	0.67 (0.48, 0.95)
Ensenada (Baja California – Pacific)	0.19 (0.14, 0.26)	0.60 (0.44, 0.86)
Guerrero Negro* (Baja California Sur – Pacific)	0.24 (0.17, 0.33)	0.74 (0.54, 1.03)
Cabo San Lucas (Baja California Sur – Pacific)	0.21 (0.16, 0.28)	0.67 (0.50, 0.94)
La Paz (Baja California Sur – Gulf of California)	0.24 (0.19, 0.31)	0.74 (0.57, 1.01)
San Felipe* (Baja California – Gulf of California)	0.22 (0.16, 0.31)	0.69 (0.50, 0.97)
Guaymas (Sonora – Gulf of California)	0.28 (0.23, 0.35)	0.80 (0.64, 1.06)
Mazatlán (Sinaloa – Pacific)	0.24 (0.20, 0.32)	0.74 (0.57, 1.01)
Puerto Vallarta (Jalisco - Pacific)	0.28 (0.21, 0.36)	0.82 (0.62, 1.11)
Manzanillo (Colima – Pacific)	0.32 (0.27, 0.39)	**0.91** (0.73, 1.18)
Lázaro Cárdenas* (Michoacán – Pacific)	0.34 (0.27, 0.43)	**0.96** (0.76, 1.25)
Acapulco (Guerrero – Pacific)	**0.44** (0.39. 0.51)	**1.16** (0.99, 1.42)
Puerto Escondido* (Oaxaca – Pacific)	0.33 (0.26, 0.42)	**0.94** (0.74, 1.23)
Salina Cruz (Oaxaca – Pacific)	0.27 (0.22, 0.34)	0.81 (0.64, 1.08)
Ciudad Madero/Tampico (Tamaulipas – Gulf of Mexico)	0.35 (0.27, 0.45)	**0.93** (0.73, 1.21)
Tuxpan (Veracruz – Gulf of Mexico)	0.33 (0.25, 0.42)	0.89 (0.69, 1.17)
Alvarado (Veracruz – Gulf of Mexico)	0.25 (0.17, 0.34)	0.73 (0.53, 1.01)
Coatzacoalcos (Veracruz – Gulf of Mexico)	0.27 (0.19, 0.36)	0.77 (0.58, 1.04)
Ciudad del Carmen (Campeche – Gulf of Mexico)	0.33 (0.25, 0.43)	**0.90** (0.70–1.18)
Progreso (Yucatán – Gulf of Mexico)	0.35 (0.28, 0.44)	**0.94** (0.75, 1.21)

[40] NASA (2023). Sea Level Projection Tool. URL: https://sealevel.nasa.gov/ipcc-ar6-sea-level-projection-tool

TABLE 6. Projected Sea Level Rise Along Mexico's Coasts in Meters by 2050 and 2100 Under SSP3-7.0 (Ref. Period 1995–2014) (*Continued*)

City (State – Body of Water)	2050 (in m)	2100 (in m)
Cancún* (Quintana Roo – Caribbean Sea)	0.33 (0.22, 0.45)	**0.91** (0.64, 1.23)
Mexico-Belize border* (Quintana Roo – Caribbean Sea)	**0.40** (0.30, 0.51)	**1.05** (0.81, 1.35)

Values in parentheses indicate 17th and 83rd percentiles. Medians bolded and shaded red indicate highest increases >0.40 m by midcentury and >0.90 m by end of century. Increases for coastal cities marked with an asterisk are based on projections for the geographic coordinates closest to Mexico's shoreline. Note the highest increases are projected for the southern Pacific and Caribbean coasts.

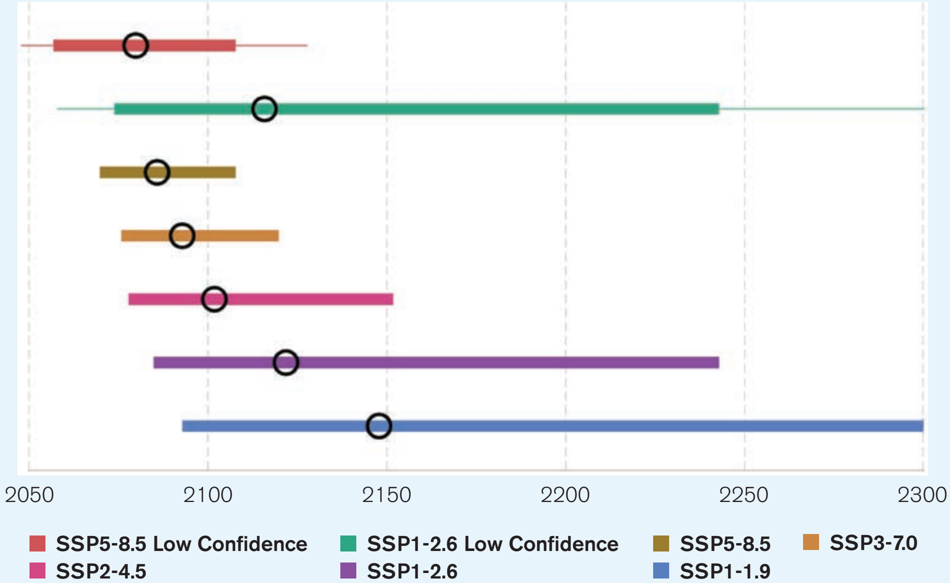
Sea level rise along Mexico's extensive coastline reveals significant regional differences under different climate scenarios.[41] Under SSP3-7.0, sea level rise is projected to increase 0.50 meters above the historical baseline in Ensenada (Baja California) by around 2090 (**see Figure 9a**). This is the slowest rate of change among Mexico's observed stations and under scenarios SSP1-2.6 and SSP2-4.5, Ensenada does not reach this threshold until after the year 2100, though with wider ranges of uncertainty. Compared to SSP3-7.0 which rises 0.60 m (0.44 m, 0.86 m) by 2100, SSP1-2.6 rises 0.39 m (0.26 m, 0.60 m) and SSP2-4.5 rises 0.49 m (0.35 m, 0.74 m) over the same timeframe. At the opposite end of the spectrum, Acapulco (Guerrero, **see Figure 9b**) is projected to experience the highest rate of sea level rise, reaching the threshold of 0.50 meters above the historical baseline much quicker (shortly after 2050) under SSP3-7.0 and with much greater certainty. At this rate, there is also very little difference between Acapulco's medium-term projections according to SSP3-7.0, SSP1-2.6, and SSP2-4.5. However, its predictions for the end of the century noticeably diverge. Sea level rise under SSP3-7.0 is projected to increase 1.16 m (0.99 m, 1.42 m) above the historical baseline by the end of the century, but 1.03 m (0.88 m, 1.28 m) under SSP2-4.5 and 0.93 m (0.78 m, 1.14 m) under SSP1-2.6 for the same timeframe. The rapid and more certain rate of increase is primarily due to Acapulco's vertical land subsidence relative to sea level, twice as high as the rates projected for most other segments of the Pacific coast. By contrast, Ensenada's sea level rise projections account for a slight increase in vertical land motion. Ocean currents, temperature, and salinity play greater factors in sea level rise along the Gulf of Mexico and Caribbean Sea, which are projected to experience increases above the national average.

Flood and Drought Risk

Incidents of both flooding and drought in Mexico will likely occur with greater intensity and frequency in the future but are strongly influenced by ENSO. Anomalously warm sea surface temperatures and weaker easterly winds in the East Pacific characterize an El Niño phase, while anomalously cool sea surface temperatures and stronger easterly winds in the East Pacific characterize a La Niña phase. Under strong El Niño conditions, summer precipitation in central and southern Mexico decreases overall, partly due to the southward shift in the ITCZ.[42] Precipitation contrastingly increases in northern Mexico during fall and winter months. Under strong La Niña

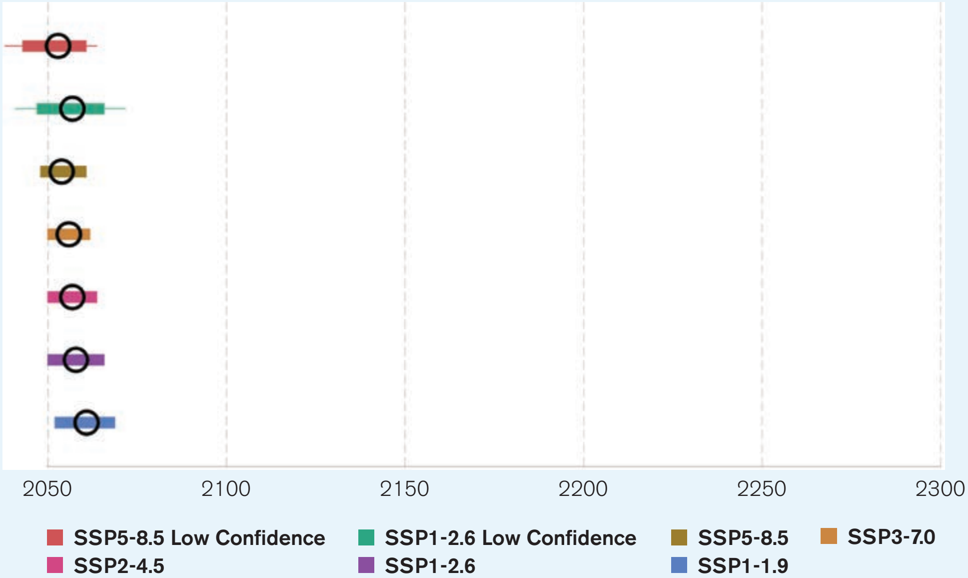
[41] NASA (2023). Sea Level Projection Tool. URL: https://sealevel.nasa.gov/ipcc-ar6-sea-level-projection-tool
[42] Dominguez, C., Jaramillo, A., and Cuéllar, P. (2021). Are the socioeconomic impacts associated with tropical cyclones in Mexico exacerbated by local vulnerability and ENSO conditions? International Journal of Climatology, 41, E3307–E3324. DOI: https://doi.org/10.1002/joc.6927

FIGURE 9A. Projected Timing of 0.5-Meter Sea Level Rise Along Ensenada's (Baja California) Coast Under Various Scenarios (Ref. Period 1995–2014)[43]



Thick bars show 17th–83rd percentile ranges, and black circles show median value. Thin bars also show 5th–95th percentile ranges for SSP1-2.6 Low Confidence and SSP5-8.5 Low Confidence scenarios.

FIGURE 9B. Projected Timing of 0.5-Meter Sea Level Rise Along Acapulco's (Guerrero) Coast Under Various Scenarios (Ref. Period 1995–2014)[44]



Thick bars show 17th–83rd percentile ranges, and black circles show median value. Thin bars also show 5th–95th percentile ranges for SSP1-2.6 Low Confidence and SSP5-8.5 Low Confidence scenarios. Note much earlier thresholds with higher certainty compared to Ensenada (**Figure 9a**).

[43] NASA (2023). Sea Level Projection Tool. URL: https://sealevel.nasa.gov/ipcc-ar6-sea-level-projection-tool
[44] NASA (2023). Sea Level Projection Tool. URL: https://sealevel.nasa.gov/ipcc-ar6-sea-level-projection-tool

conditions, summer precipitation increases in central and southern Mexico while decreasing in northern Mexico, especially in the winter months. Such interannual cycles exacerbate Mexico's unequally distributed water resources, as the country's central and northern regions make up roughly two-thirds of the population yet possess only one-third of the nation's water resources.[45] Furthermore, rainfed aquifers supply most urban and rural areas, industrial uses, and a sizable proportion of irrigation needs, underscoring the implications for water resource management.

By midcentury under a high emissions scenario, Mexico is expected to endure a 15% increase in hydrological drought frequency.[46] An extremely high level of water stress expected by midcentury will particularly affect the Mexico City metropolitan region and the Rio Grande River basin. The major drought that occurred in the country's north between 2010–2012 offers a recent example, resulting in agricultural losses and economic damages worth $7.4 billion pesos.[47] The impacts of water scarcity on agriculture will increasingly affect the Baja California Peninsula, Northeast, and state of Campeche in the future,[48] while the repercussions of lower water availability on hydropower generation will affect the Mexico's tropical south and east.

At the same time, despite widespread projected decreases in annual precipitation, the frequency of intense precipitation events continues to increase and pose risks to human settlements and critical infrastructure. A recent example occurred in 2010 when two days of heavy rain caused the La Compañía and Los Remedios rivers to overflow their riverbanks in the state of México, leaving $1 billion pesos worth of damage.[49] River basins on the Gulf coast and in Chiapas may experience more frequent and intense flooding leading to annual economic losses of USD$6.5–$9.8 billion by midcentury.[50] The regions with the highest vulnerability to floods according to the national government include the Mexico City metropolitan area, Michoacán, and Oaxaca, but vulnerability in the future will increase most for the Baja California Peninsula and the Northeast.[51]

Tropical cyclones account for up to half of seasonal precipitation in Mexico – especially in arid and semiarid regions – but pose serious recurrent threats as the frequency of extreme storms increase.[52] On the Atlantic side, the national government identifies the areas with the highest risk of more frequent, intense tropical cyclones as the entire Yucatán Peninsula and parts of northern Veracruz and Tamaulipas.[53] This encompasses areas important to tourism

45 CMCC (2021). G20 Climate Risk Atlas: Mexico. URL: https://files.cmcc.it/g20climaterisks/Mexico.pdf
46 CMCC (2021). G20 Climate Risk Atlas: Mexico. URL: https://files.cmcc.it/g20climaterisks/Mexico.pdf
47 CENAPRED (2022). Eventos relevantes asociados a peligros en México desde 1810. URL: http://www.atlasnacionalderiesgos.gob.mx/archivo/MapaFenomenos_1810.html
48 INECC. (2019). Atlas Nacional de Vulnerabilidad al Cambio Climático México. 1st Edición. Instituto Nacional de Ecología y Cambio Climático. México. URL: https://atlasvulnerabilidad.inecc.gob.mx/page/fichas/ANVCC_LibroDigital.pdf
49 CENAPRED (2022). Eventos relevantes asociados a peligros en México desde 1810. URL: http://www.atlasnacionalderiesgos.gob.mx/archivo/MapaFenomenos_1810.html
50 CMCC (2021). G20 Climate Risk Atlas: Mexico. URL: https://files.cmcc.it/g20climaterisks/Mexico.pdf
51 INECC. (2019). Atlas Nacional de Vulnerabilidad al Cambio Climático México. 1st Edición. Instituto Nacional de Ecología y Cambio Climático. México. URL: https://atlasvulnerabilidad.inecc.gob.mx/page/fichas/ANVCC_LibroDigital.pdf
52 Dominguez, C., Jaramillo, A., and Cuéllar, P. (2021). Are the socioeconomic impacts associated with tropical cyclones in Mexico exacerbated by local vulnerability and ENSO conditions? International Journal of Climatology, 41, E3307–E3324. DOI: https://doi.org/10.1002/joc.6927
53 CONAGUA (2021). Análisis de frecuencia e intensidad de ciclones tropicales en las cuencas de los municipios costeros. CENAPRED. URL: https://mapas.inecc.gob.mx/apps/SPCondicionesNA/Ciclones_Tropicales.html

and offshore oil production. Among the most impactful storms to affect these regions, Hurricane Wilma in 2005 cost billions of pesos when it stalled near Cancún.[54] On the Pacific side, the highest-risk areas include the stretch of coastline between Acapulco (Guerrero) and Puerto Vallarta (Jalisco), the vicinity of Mazatlán (Sinaloa), and Baja California Sur. Among the most impactful storms were Hurricane Pauline (1997) along the southern coast, which caused $2.8 billion pesos in damage and more than 100 casualties;[55] Hurricane Manuel and Ingrid (2013) along the western coast, which caused $58 billion pesos in damage and over 200 casualties;[56] and Hurricane Patricia (2015) which became the strongest tropical cyclone on record in the Eastern Pacific. Tropical cyclone days and extreme rainfall increase along Mexico's northwest and southern (Pacific) coasts during neutral phases of ENSO.[57] El Niño years tend to produce fewer tropical cyclone days and total rainfall in the Northeast and East (Gulf and Caribbean coasts), while La Niña years tend to produce above average tropical cyclone days and rainfall in these regions. The effects of climate change on tropical cyclones and future ENSO patterns are therefore important for predicting Mexico's longer-term extreme precipitation and flood conditions.

Earthquake, Volcano, and Landslide Hazards

Climate variability exacerbates high seismic risks that threaten much of the country's most densely populated centers. Mexico is located along the Pacific Ring of Fire where the North American Plate meets the Pacific and Cocos Plates, forming three distinct seismic regions (**see Figure 10a**). Starting in the north, the undersea Gulf of California Rift Zone (GCRZ) constitutes the first region and runs from the terminus of the San Andreas Fault near the Colorado River Delta south down the entire length of the gulf.[58] It acts as the divergent axis between the North American Plate to the east and the Pacific Plate to the west, which includes the Baja California Peninsula. The second important seismic region is associated with the Cocos Plate and Rivera Plate – a microplate that used to extend from the Cocos Plate and connects to the Gulf of California Rift Zone off the coast of Mazatlán. A divergent spreading zone at the western boundaries of both the Rivera and Cocos Plates forces these plates north-northeast where they subduct beneath the North American Plate along long Middle America Trench (MAT). This 3,000 km long trench reaches depths greater than 6,000 m and parallels Mexico's southern Pacific coast.[59] Subduction especially near Guerrero and Oaxaca generates shallow earthquakes and contributes

[54] Appendini, C. M., Meza-Padilla, R., Abud-Russell, S., Proust, S., Barrios, R. E., and Secaira-Fajardo, F. (2019). Effect of climate change over landfalling hurricanes at the Yucatan Peninsula. Climatic Change, 157, 469–482. DOI: https://doi.org/10.1007/s10584-019-02569-5

[55] CENAPRED (2022). Eventos relevantes asociados a peligros en México desde 1810. URL: http://www.atlasnacionalderiesgos.gob.mx/archivo/MapaFenomenos_1810.html

[56] Appendini, C. M., Meza-Padilla, R., Abud-Russell, S., Proust, S., Barrios, R. E., and Secaira-Fajardo, F. (2019). Effect of climate change over landfalling hurricanes at the Yucatan Peninsula. Climatic Change, 157, 469–482. DOI: https://doi.org/10.1007/s10584-019-02569-5

[57] Dominguez, C., Jaramillo, A., and Cuéllar, P. (2021). Are the socioeconomic impacts associated with tropical cyclones in Mexico exacerbated by local vulnerability and ENSO conditions? International Journal of Climatology, 41, E3307–E3324. DOI: https://doi.org/10.1002/joc.6927

[58] Fletcher, J. M., and Munguia, L. (2000). Active continental rifting in southern Baja California, Mexico: Implications for plate motion partitioning and the transition to seafloor spreading in the Gulf of California. Tectonics, 19(6), 1107–1123. DOI: https://doi.org/10.1029/1999TC001131

[59] Ramírez-Herrera, M. T., Kostoglodov, V., and Urrutia-Fucugauchi, J. (2011). Overview of recent coastal tectonic deformation in the Mexican subduction zone. Pure and Applied Geophysics, 168, 1415–1433. DOI: https://doi.org/10.1007/s00024-010-0205-y

to active volcanic activity in the third important seismic region in Central Mexico. The Cordillera Neo-Volcánica or Trans-Mexican Volcanic Belt (TMVB) encompasses a complex 1,000 m long series of rifts, ridges, and hundreds of volcanic formations from the Pacific coast to the Gulf of Mexico (mapped in detail by Ferrari et al).[60] Six of Mexico's ten largest metropolitan areas are located in or near this region, including: Guadalajara (Jalisco), León (Guanajuato), Querétaro (Querétaro), Toluca (México), Mexico City (Ciudad de México), and Puebla (Puebla). The WBG's GFDRR classifies populations located within 50 km from a potentially active volcano as having high volcanic hazard risk, which include the following states: Nayarit, Jalisco (but not Guadalajara), Colima, México, Ciudad de México, Morelos, Tlaxcala, Puebla, and Chiapas.[61] Michoacán and Veracruz also have large populations exposed to medium-level volcano hazard risk. The deadliest eruption in modern times occurred in 1982, when El Chichón (Chiapas) killed more than 2,000 people.[62] The most recent volcanic eruptions include Colima (Jalisco/Colima) in 2019 and Popocatépetl just outside of Mexico City (México/Morelos/Puebla) in 2023.[63]

The Global Earthquake Model (GEM) Foundation identifies the greatest potential for seismic movement – peak ground acceleration > 0.55 g with a 10% probability of being exceeded in 50 years – in areas closest to the Middle America Trench such as Manzanillo (Colima) and Acapulco (Guerrero), in addition to Mexicali (Baja California).[64] Historical catalogues of seismic activity (**see Figure 10b**) likewise confirm the highest number of earthquakes with magnitudes greater than 7.0 had epicenters located between the Middle America Trench and the Trans-Mexican Volcanic Belt. A considerable portion of earthquakes >4.0 magnitude occurred offshore, posing tsunami risks. All states on the Pacific coast (except Sonora) have a high associated risk (>40% probability) of experiencing a potentially damaging tsunami in the next 50 years.[65] According to GEM, the states with the highest annual average earthquake losses (> USD$200 million) are Baja California, Chiapas, Oaxaca, Guerrero, and México. Cities with medium-level earthquake hazard risk such as Guadalajara (Jalisco), Mexico City (Ciudad de México), and Puebla (Puebla) would also experience significant losses. Some notable seismic events in recent years include: the 8.1 magnitude Michoacán earthquake (1985), which resulted in as many as 9,500 casualties and $4.1 billion pesos in damage; the 7.2 magnitude El Mayor-Cucapah earthquake (2010), which resulted in $8.1 billion pesos in damage; the 8.2 magnitude Tehuantepec earthquake (2017), which resulted in 98 casualties and $19.2 billion in damage; and the 7.1 magnitude Puebla earthquake (2017), which resulted in more than 300 casualties and $61 billion in damage.[66]

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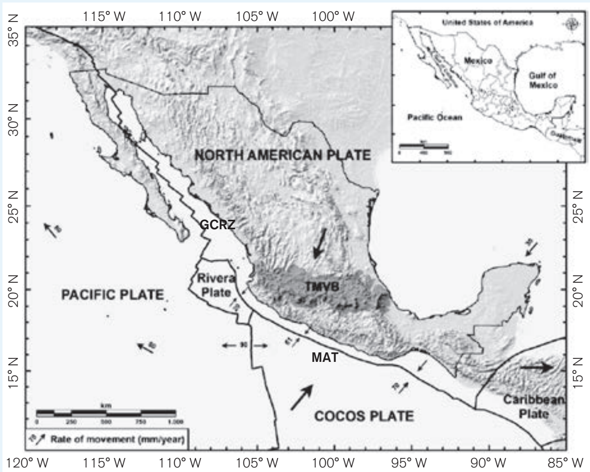
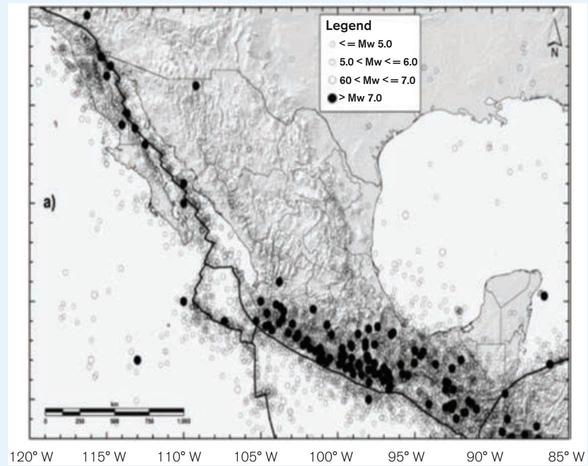
60 Ferrari, L., Orozco-Esquivel, T., Manea, V., and Manea, M. (2012). The dynamic history of the Trans-Mexican Volcanic Belt and the Mexico subduction zone. Tectonophysics, 522, 122–149. DOI: https://doi.org/10.1016/j.tecto.2011.09.018
61 Global Facility for Disaster Risk Reduction (2020). Mexico. URL: https://thinkhazard.org/en/report/162-mexico
62 CENAPRED (2022). Eventos relevantes asociados a peligros en México desde 1810. URL: http://www.atlasnacionalderiesgos.gob.mx/archivo/MapaFenomenos_1810.html
63 Smithsonian Institution (2023). Mexico Volcanoes. National Museum of Natural History Global Volcanism Program. URL: https://volcano.si.edu/volcanolist_countries.cfm?country=Mexico
64 Global Earthquake Model Foundation (2019). Mexico. URL: https://downloads.openquake.org/countryprofiles/MEX.pdf
65 GFDRR (2020). Mexico. URL: https://thinkhazard.org/en/report/162-mexico
66 CENAPRED (2022). Eventos relevantes asociados a peligros en México desde 1810. URL: http://www.atlasnacionalderiesgos.gob.mx/archivo/MapaFenomenos_1810.html

FIGURE 10A. Mexico's Key Seismic Features[67]



Note arrows indicating collision and subduction of both the Rivera Plate and Cocos Plate (moving north-northeast) beneath the North American Plate along the length of the Middle America Trench (MAT). The Gulf of California Rift Zone (GCRZ) extends northward and the Trans-Mexican Volcanic Belt (TMVB) near the southern edge of the North American Plate is shaded gray.

FIGURE 10B. Recorded Earthquakes (Magnitude > 4.0), 1787–2018[68]



Note the largest number of earthquakes with a magnitude greater than 7.0 are centered between the Middle America Trench and the Trans-Mexican Volcanic Belt.

Landslides and various types of mass movement can be influenced by an array of factors, ranging from seismic activity, geology, slope, water saturation, and erosion, all of which have the potential to be exacerbated by human activities. The national government identifies the states with the greatest vulnerability to landslides as Michoacán, Sonora, and Chihuahua, though the states of Guerrero, Colima, and Baja California Sur have greater exposure and sensitivity.[69] The deadliest landslides in the last 25 years were driven by rain, including in: Acapulco (Guerrero) after Hurricane Pauline in 1997, which killed 120 people; Teziutlán (Puebla) after a tropical depression in 1999, which killed 110 people; and La Pintada (Guerrero) after Hurricane Manuel in 2013, which killed more than 70 people.[70]

Key National Documents

- Third Biennial Update Report (2022) (Spanish)
- Updated General Law on Climate Change (2022) (Spanish)
- Second Updated Nationally Determined Contribution (2022) (Spanish)
- First Updated Nationally Determined Contribution (2020)
- Updated Sixth National Communication to the UNFCCC and Second Biennial Update Report (2019) (Spanish)

[67] Sawires, R., Santoyo, M. A., Peláez, J. A., and Corona Fernández, R. D. (2019). An updated and unified earthquake catalog from 1787 to 2018 for seismic hazard assessment studies in Mexico. Scientific data, 6(1), 241. DOI: https://doi.org/10.1038/s41597-019-0234-z

[68] Sawires, R., Santoyo, M. A., Peláez, J. A., and Corona Fernández, R. D. (2019). An updated and unified earthquake catalog from 1787 to 2018 for seismic hazard assessment studies in Mexico. Scientific data, 6(1), 241. DOI: https://doi.org/10.1038/s41597-019-0234-z

[69] INECC. (2019). Atlas Nacional de Vulnerabilidad al Cambio Climático México. 1st Edición. Instituto Nacional de Ecología y Cambio Climático. México. URL: https://atlasvulnerabilidad.inecc.gob.mx/page/fichas/ANVCC_LibroDigital.pdf

[70] CENAPRED (2022). Eventos relevantes asociados a peligros en México desde 1810. URL: http://www.atlasnacionalderiesgos.gob.mx/archivo/MapaFenomenos_1810.html

- National Inventory Report (2018) (Spanish)
- Climate Change Mid-Century Strategy (2016)
- Intended Nationally Determined Contribution (2015)
- Climate-Smart Agriculture (CSA) Profile (2015)
- First Biennial Update Report (2015)
- National Climate Change Strategy 10-20-40 Vision (2013)
- Fifth National Communication to the UNFCCC (2012) (Spanish)
- Fourth National Communication to the UNFCCC (2010) (Spanish)
- Third National Communication to the UNFCCC (2006) (Spanish)
- Second National Communication to the UNFCCC (2001) (Spanish)
- First National Communication to the UNFCCC (1997)

ANNEX OF PROJECTED CLIMATE SCENARIOS

Compared to scenario SSP3-7.0, which results in the greatest temperature and precipitation shifts nationally across all key metrics by the end of the century (see Table 7), SSP1-2.6 and SSP2-4.5 demonstrate Mexico's lower overall rates of change and severity of climate impacts as a result of carbon emission reductions. The differences between projected temperatures under the three scenarios are particularly pronounced (**see Figure 11a**). SSP1-2.6 has the lowest annual mean temperature increase – an anomaly greater than 1°C by 2080–2099. Mean temperature rises by an anomaly greater than 2°C by end-of-century under SSP2-4.5 and greater than 3.5°C by end-of-century under SSP3-7.0. The difference in the anomalous number of tropical nights (T-min >20°C) experienced nationally by the end of the century under SSP1-2.6 and SSP2-4.5 (roughly one month more than the reference period) varies by a magnitude of half that of SSP3-7.0 by the end of the century (roughly two months more than the reference period). The number of days consisting of warm spells increases significantly from the reference period under SSP3-7.0, with its midcentury anomaly more than tripling from its 2020–2039 anomaly and its 2080–2099 anomaly spanning roughly half of an average year. By comparison, the number of warm spell days under SSP2-4.5 is a couple months lower by end of the century and under SSP1-2.6 changes very little from the 2040–2059 period.

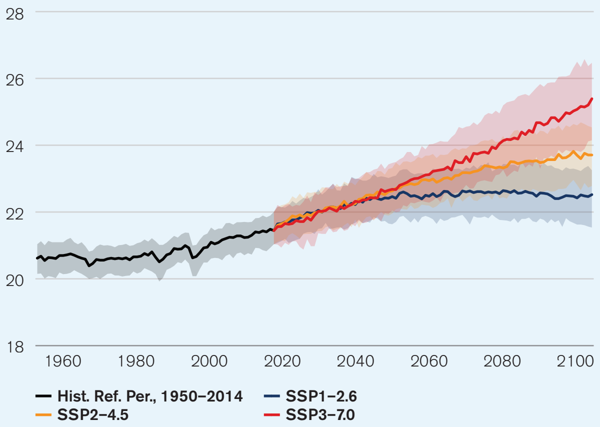
The projected precipitation patterns countrywide under the three scenarios produce noticeable differences by end of century, underscoring the shift in potential precipitation duration and intensity under higher emission trajectories (**see Figure 11b**). By the period 2080–2099, Mexico is expected to experience virtually no change in precipitation from the reference period under SSP1-2.6, but a net negative trend under SSP2-4.5 and a negative trend twice that of SSP2-4.5 under SSP3-7.0. The average largest 5-day cumulative precipitation increases only marginally from the reference period under all three scenarios by end-of-century. However, under SSP3-7.0, the upper threshold of probable precipitation (90th percentile of 84.50 mm) is higher for 2080–2099. A key measure of meteorological drought – maximum consecutive dry days annually – remains relatively unchanged from the reference period's median (168.52 days) and increases only slightly under all scenarios.

TABLE 7. Key National-Level Projected Anomalies Through End-of-Century (Ref. Period 1995–2014) Under SSP1-2.6, SSP2-4.5, and SSP3-7.0 Scenarios

Metric	SSP1-2.6 Projection		
	2020–2039	**2040–2059**	**2080–2099**
Annual Mean Temperature	0.88°C (0.52°C, 1.17°C)	1.25°C (0.77°C, 1.71°C)	1.27°C (0.71°C, 1.98°C)
Tropical Nights (No. Nights T-min >20°C) Annually	15.10 (7.87, 22.94)	21.58 (12.35, 31.86)	22.00 (11.37, 35.65)
Warm Spell Duration Index (No. Days Annually)	22.73 (–3.97, 60.05)	45.78 (4.86, 87.76)	**58.39** (5.77, 107.89)
Percent Change in Annual Total Precipitation	–0.46% (–10.22%, 9.89%)	–0.46% (–10.06%, 10.36%)	–0.48% (–10.80%, 11.10%)
Average Largest 5-Day Cumulative Precipitation (mm) Annually	10.17 (–45.94, 66.37)	9.60 (–50.21, 65.74)	11.69 (–46.29, 69.17)
Max. No. Consecutive Dry Days Annually	4.89 (–39.75, 48.60)	4.07 (–36.41, 49.94)	5.09 (–38.27, 50.48)
Metric	**SSP2-4.5 Projection**		
	2020–2039	**2040–2059**	**2080–2099**
Annual Mean Temperature	0.90°C (0.55°C, 1.26°C)	1.53°C (1.08°C, 1.99°C)	**2.39°C** (1.70°C, 3.08°C)
Tropical Nights (No. Nights T-min >20°C) Annually	15.89 (8.61, 23.47)	26.66 (17.74, 36.72)	**41.19** (27.95, 56.46)
Warm Spell Duration Index (No. Days Annually)	26.99 (–4.12, 66.34)	**63.40** (21.82, 116.45)	**123.65** (55.45, 181.65)
Percent Change in Annual Total Precipitation	–1.70% (–10.73%, 7.41%)	–3.37% (–14.44%, 8.15%)	–5.42% (–16.37%, 7.23%)
Average Largest 5-Day Cumulative Precipitation (mm) Annually	9.34 (–46.30, 67.49)	12.94 (–47.02, 72.21)	14.88 (–47.41, 77.24)
Max. No. Consecutive Dry Days Annually	3.18 (–38.89, 50.60)	7.32 (–34.52, 52.32)	12.57 (–34.36, 58.77)
Metric	**SSP3-7.0 Projection**		
	2020–2039	**2040–2059**	**2080–2099**
Annual Mean Temperature	0.82°C (0.47°C, 1.21°C)	1.63°C (1.20°C, 2.20°C)	**3.55°C** (2.65°C, 4.48°C)
Tropical Nights (No. Nights T-min >20°C) Annually	14.87 (7.26, 23.10)	29.01 (19.58, 40.83)	**62.09** (45.21, 84.53)
Warm Spell Duration Index (No. Days Annually)	24.10 (–1.89, 59.12)	**74.81** (34.73, 125.09)	**179.59** (120.94, 231.72)
Percent Change in Annual Total Precipitation	–1.90% (–11.95%, 9.86%)	–4.65% (–15.84%, 6.98%)	**–9.61%** (–27.02%, 6.86%)
Average Largest 5-Day Cumulative Precipitation (mm) Annually	5.13 (–61.35, 67.12)	10.59 (–56.93, 73.90)	12.26 (–55.95, 84.50)
Max. No. Consecutive Dry Days Annually	4.19 (–38.07, 46.37)	7.99 (–31.75, 51.78)	**16.51** (–27.34, 62.73)

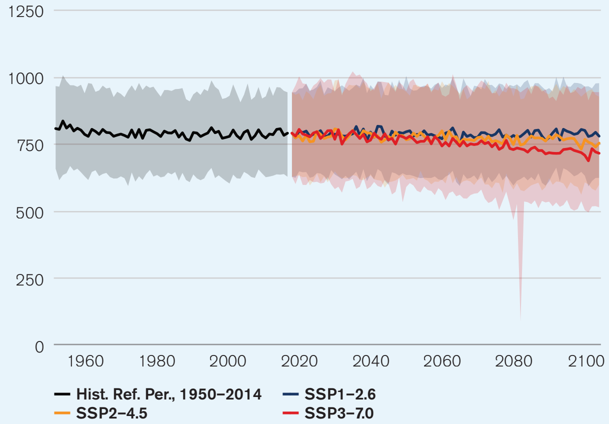
10th percentile and 90th percentile values are shown in parentheses. Key values or shifts over time are shaded orange and bolded. Projected warm spells (according to the Warm Spell Duration Index) and maximum consecutive dry days use 1.00° × 1.00° (100km × 100km) data resolution. See text for interpretation.

FIGURE 11A. Projected Average Mean Temperature in Degrees Celsius Nationwide (Ref. Period 1995–2014) Under Various Scenarios



Shaded areas indicate ranges of 10th–90th percentiles. Note clearly higher increase of SSP3-7.0 starting midcentury.

FIGURE 11B. Projected Precipitation in Millimeters Nationwide (Ref. Period 1995–2014) Under Various Scenarios



Shaded areas indicate ranges of 10th–90th percentiles. Note relative decline under SSP3-7.0 by the end of the century, but probability ranges also extend above the historical reference period for all scenarios, indicating a potential likelihood for precipitation increases rather than decreases.

CLIMATE RISK COUNTRY PROFILE

MEXICO

WORLD BANK GROUP